Industrial QUALITY CONTROL

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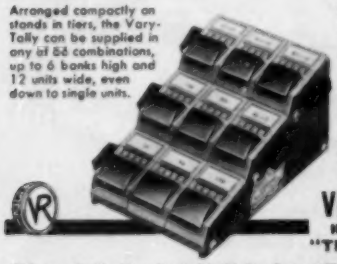

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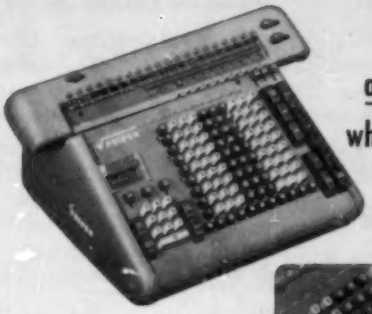

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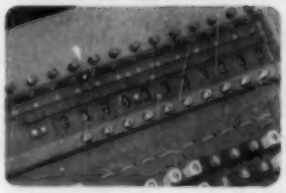

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From the President's Desk

Quality Control Is People

There is nothing new or novel in the caption to these remarks. It has been said in so many ways so many times by so many persons as to make its assertion here seem redundant.

Redundant or not, we can scarcely repeat too often the simple fact that quality control shares the common dependence that any science must place on the human factor to translate it into action. From control charts to controlled experiments, quality control proves out on paper to be a science custom-built to solve industrial quality-cost problems.

But quality control on paper is sterile. It is quality control in action that counts. And quality control in action is people any way you want to look at it!

We in ASQC think of quality control as a professional engineering science. We think of our Society as the organization devoted to the task of developing this science. This is entirely proper and necessary. Industry has always had quality control in one form or another. But quality control as an engineering science responsible for the planning and administration of the total quality control function in its modern sense, and existing as a vital and recognized arm of management, is the ultimate objective.

In mobilizing our effort toward the attainment of this objective, we must keep it *people*-oriented. We do not lack for techniques. The science of quality control already has an ample supply of technical tools mathematically, statistically, engineering-wise, and management-wise. These will be refined and expanded as time goes on.

The problem is to get the tools of this science *understood*, to get them *accepted*, and to get them *used*. This has always been the major problem and probably always will be. It cannot be solved by education alone. It cannot be solved by organizational structure alone. It cannot be solved by company policy alone. It cannot be solved by directive alone. It cannot be solved by theory alone. These are all necessary ingredients, for without theory, without training, without recognized lines of communication and authority, without sincere management endorsement and support neither understanding, acceptance, or use is possible in any effective way.

But the common denominator in all this is still people. If the principles and practice of modern scientific quality control are to move forward to achievement of the intrinsic potential they possess for industry, they must be packaged and sold in terms of people.

So we come back to where we started: just a note to remind ourselves to think and act and build in terms of the people on whom the science of quality control must depend and for whose security and enrichment it is intended, for when all is said and done, the basic fact still remains that

QUALITY CONTROL IS PEOPLE!

Dale L. Lobenziger

Significance Tests and the Dollar $ign

FRED C. LEONE, R. B. NOTTINGHAM, JACK ZUCKER*

Introduction

Standard tests of statistical significance of differences between samples of known and unknown populations such as the t, χ^2, and F tests are among the most important tools of the quality control engineer. The conventional and rigorous application of these tests is generally understood. However, these tests as usually applied have two major deficiencies: (1) statistical significance does not always represent monetary significance and (2) in the instance where statistical significance is not established, nothing is accomplished except our knowledge of the failure of the experiment to reveal a significant difference, and we are often left in an inconclusive and unsatisfying position. By the application of known statistical methods to the data involved in the performance of these tests it is possible to go a long way toward establishing rigorous limits for conclusions even in the case of nonsignificance.

In the application of the conventional methods, the engineer is likely to find himself in a situation like this: Engineer I. Q. Ibble is investigating a proposed new method for the manufacture of widgets. His company has been manufacturing widgets by the same method for a number of years. The statistics of the process are well known. Due to the high cost of experimental widgets, Ibble has limited his experiment to a sample of 25.

The measurements of the key property of widgets fabricated under the proposed method are brought to the quality control engineer, Exbar Andar, for analysis. After considerable discussion regarding several numbers (are they fours or nines?) Andar accepts the data and performs the standard χ^2 and t tests. He hopes that his previous missionary sessions have had results in that I. Q. Ibble's data are of adequate precision and are a homogenous sample.

The following day, Ibble returns and the dialogue goes something like this:

Ibble: "Well, is the new method better?"

Andar: "Possibly, but from this sample I couldn't guarantee it."

Ibble: "Come on, the average of the new method was higher than the average of the standard."

Andar: "Yes, but this is not significant."

Ibble: "Significant, shmignificant! Is it or isn't it better?"

Andar: "Well, the odds are only five-to-one against getting a difference this large, due only to chance variation."

Ibble: "So-o-! Those are good odds!"

Andar: "Remember, we're not betting on horses. Good industrial statistical practice says we should have odds of at least 19 to 1. I'm sorry, but these results aren't good enough to really say for sure."

Ibble: "So what happens now?"

Andar: "Well, if you really want to find out if there's any improvement, try a larger sample. How about a hundred?"

Ibble: "Do you realize what these widgets cost? To heck with the new process; we can't spend that kind of money unless we have a good chance of success."

I. Q. Ibble departs in a 1957 Huff.

Ibble's parting shot in this hypothetical dialogue presents the usual industrial problem—at that point, the dollar sign rears its ugly head. Whether a new process is more desirable than an old, whether one proposed process is better than a second, whether additional experimentation is warranted, is dependent upon a complex consideration of the cost of experimentation, the cost of converting the process, etc., versus the probable, or possible advantages to be gained. Management and the engineer should have the answer to the first part, but it is the duty of the industrial statistician to provide the second answer.

This article proposes to take these same tests of significance that Mr. Exbar Andar would normally utilize in obtaining his inconclusive responses to this type of question, and operate on them to obtain a definite reply to the questions:

(1) What are my odds that the new process or product is better than the old? and

(2) How much better might it be?

It may be observed that no attempt is being made to alter the existing statistical significance tests nor to introduce drastically new tests of significance. The purpose is rather to extend the standard techniques to provide management with the true odds involved in their risk of capital. For example, management has decided that a new process must be K percent better than an old one, based on various criteria, and a standard test indicates a significant difference between the processes. When the

*Mr. Leone is with the Case Institute of Technology, Cleveland, Ohio. Messrs. Nottingham and Zucker are with Brush Electronics Co., Cleveland, Ohio.

indicated minimum increase is greater than the specified K percent, the new process has achieved, to given odds, at least the required improvement. When the maximum increase is less than K percent to a given probability the new process will not produce the desired K percent improvement. When K percent is between the minimum and maximum, a larger sample is required, but the facts are available to make a decision, on a financial basis, of the economics of such an effort.

What happens when there is no significant difference between the processes? Essentially the same procedure described above is followed except that rather than being interested in significance, we concern ourselves with the possible limits of difference, to a given probability. In other words, the confidence limits about a sample statistic provide the dollars and "sense" answers for a change over, a continuance of the status quo, or an additional sample.

The question may be raised, "Why bother with standard statistical tests of significance?" Where differences are significant there is indication of a definite change having been made. The nomograms presented with this article indicate a means of measuring the sufficiency of the change. Where differences may be attributable to chance variation, the nomograms indicate the possible limits of the differences.

The Problem

The problem will be divided into three parts:

(1) a new process mean versus an established mean,

(2) a new process variance versus an established variance, and

(3) the choice between two variances.

In each case the problem will be stated, a method of attack will be presented, and, finally, an example will be carried out.

CASE 1

Suppose we consider the problem given in the introduction. A corporation has been manufacturing an article for some time. A new method is proposed for improving the product and a sample of 25 is taken from this new method. A simple test of significance is carried out. Let us say we wish 95 percent confidence in our conclusion. Then, the statistic would be

$$t = \frac{\overline{X} - \mu_o}{S / \sqrt{N}} \qquad (1)$$

where $\overline{X}$, S and N are the sample mean, standard deviation, and size respectively, and μ_o is the mean of the previously established process. Here, S is defined as $\left[\sum_{i=1}^{N} (X_i - \overline{X})^2/(N-1) \right]^{1/2}$. On the basis of this simple t test of significance one of two conclusions will be drawn. Either the difference is significant with the desired confidence (here 95 percent), or it is not. In either case, we may not be satisfied with this conclusion.

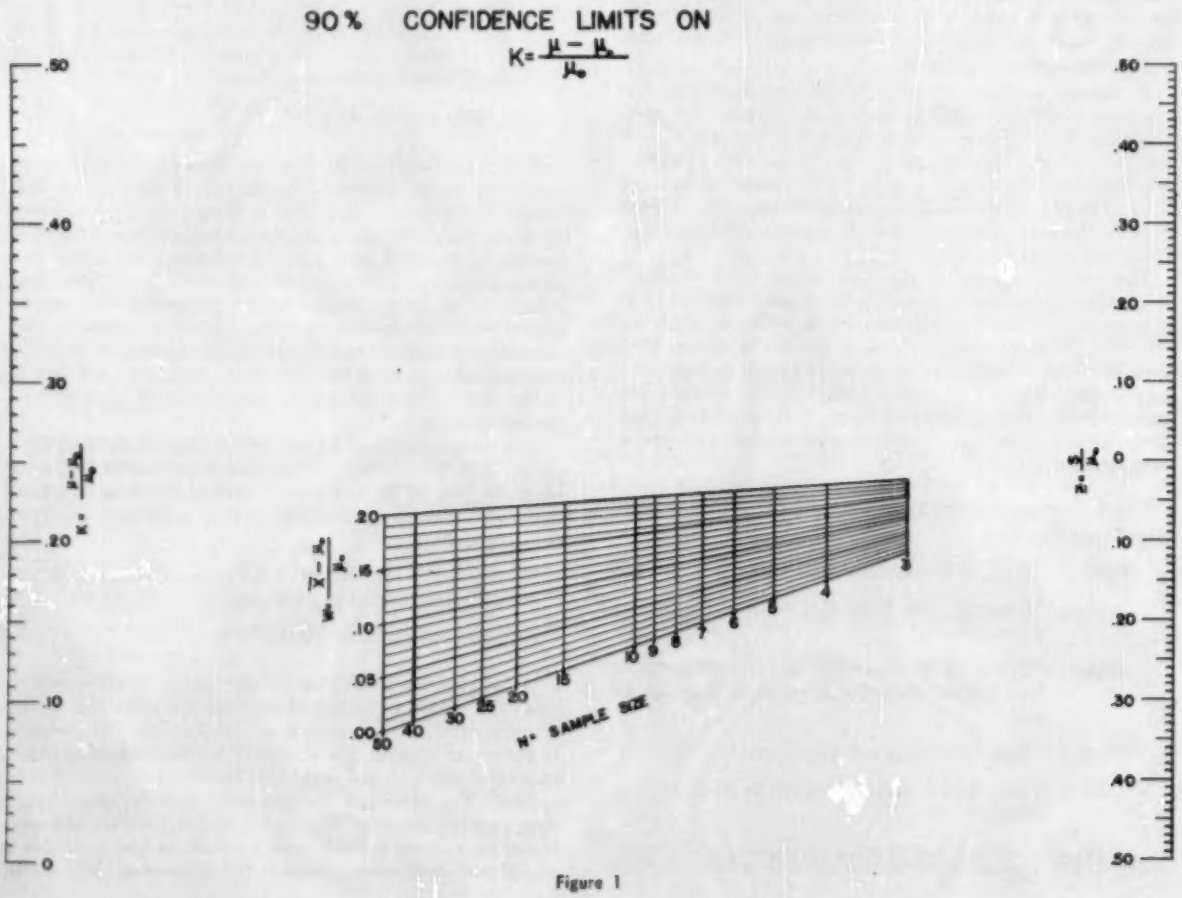


Figure 1

Suppose, for example, this difference is significant, but the confidence interval on this difference is less than a desired relative change. Then, even though we have a specific conclusion, the change in process is still not warranted. What we propose to do, by means of Figures 1, 2, and 3, is to obtain the upper and lower limits of the relative change

$$K = \frac{\mu - \mu_o}{\mu_o} \qquad (2)$$

where μ is the true (but presently unknown) mean of the new process, and μ_o is the true mean of the present process. K, then, is the relative improvement of the new process over the old. Now, in an actual situation, the desired relative change will be specified in advance, say K′. The mathematics of the solution may be found in equations 9 to 11.

Let us take each of the two alternatives stated above, significance and non-significance. Suppose we have found a significant difference between $\overline{X}$ and μ_o. Suppose we continue, by means of our nomogram, and find that the confidence limits on K (with 95 percent or any other specified confidence) are K_1 and K_2. If K′ is less than K_1, the lower confidence limit, then our sample has told us that our new process has a mean which is at least 100K′ percent greater than the present mean. If, on the other hand, K′ is greater than K_2, the upper confidence limit, then our sample has told us that even though we may have a significant difference, this difference is not enough to warrant a change. Finally, if K′ is between K_1 and K_2, our sample has not given us conclusive information. There is, however, sufficient information regarding the statistical aspects of the proposed investment to determine the feasibility of taking another sample or forgetting the entire matter. If the difference between $\overline{X}$ and μ_o were not significant, the question is asked whether the required percent difference could be achieved on the assumption that a true difference does exist but has not been discovered by this sample. The same work would be carried out as above on nomograms 1, 2 and 3.

Nomograms 1, 2 and 3 are used to find the $(1-\alpha)$ confidence limits on K, the relative change in the true mean of the population. The data required are μ_o, N, $\overline{X}$ and S. Determine

$$w = \frac{\overline{X}-\mu_o}{\mu_o} \text{ and } Z = S/\mu_o$$

and enter the nomogram of the desired confidence as follows: With N as the abscissa and w as the ordinate determine a point on the (N,w) grid. The value $Z = S/\mu_o$ gives us two points on the Z line, say Z_1 and Z_2, with Z_1 on the upper part of the line and Z_2 on the lower part. A straight line through the point Z_1 and the point (N,w) on the grid determines the lower limit on the K scale. A line through the points Z_2 and (N,w) determines the upper limit on the K scale.

The following example of the use of these nomograms illustrates the condition where statistical significance exists but significant monetary difference is not present. The dielectric constant of material utilized in the manufacture of piezoelectric ceramic elements varies, sometimes considerably, from lot to lot of material. To determine the constant for each lot, a material sample is obtained. Twenty-four elements are fabricated. The average dielectric constant for the lot is estimated by measuring the average element capacity and obtaining

$$D = \frac{C\ t}{0.2244A}$$

where D = dielectric constant

C = element capacity

t = element thickness

A = electroded area

(0.2244 = dimensional constant)

The dielectric constant required varies from element to element, as do the tolerances. For one common element, D = 1937 ± 8.0%.* A sample of 24 elements fabricated from a material sample indicated $\overline{D}$ to be 1937 − 4% = 1860* and S = 23. Is the "actual" D within the specification with 95 percent confidence?

Generally, an answer to this type of problem is given by performing the standard t test. For this example

$$t = \frac{1937 - 1860}{23 / \sqrt{24}} = 16.4$$

The critical value of t for this sample size is $t_{23,0.025} = 2.069$. Statistically, this is "highly significant," i.e., variations from the nominal are considered as definitely not due to chance and there is at least 95 percent confidence that the data results from a statistically unsatisfactory lot of material.

But is this material unsatisfactory from the engineer's point of view? It should be recognized that the engineering specifications for this material were not set by statistical theory but by practical industrial considerations. The true problem, then, is to combine statistical theory with practical, non-statistical engineering to determine whether the sample meets the specification with 95 percent confidence in this case, not whether the sample is the same or different from the nominal.

For most situations, the set of nomograms will be sufficient. Since the $(1-\alpha)$ confidence level is 95 percent, use Fig. 2. Proceed as follows:
Determine

$$w = \frac{\overline{X} - \mu_o}{\mu_o} = -0.04$$

Obtain the point N = 24, |W| = 0.04‡ on the central grid. On the scale, obtain the points $Z = S/\mu_o = 0.012$ above and below Z = 0. The line from the upper Z through the point (N,|w|) gives the lower 95 percent confidence limit on K of 0.036. The line from the lower Z through (N,|w|) gives the upper 95 percent confidence limit on K of 0.046. A change of signs then gives us −0.046 and −0.036 as the lower and upper confidence limits, respectively, for this negative difference. In other words, based on this sample of 24 elements and the desired confidence, dielectric constant of the material is no worse than 4.5 percent lower than the nominal, but well within the 8.0 percent difference permissible. Thus, it is seen that the lot is statistically different from the nominal but within the engineering tolerance. Hence, it is acceptable for fabrication of ceramic elements.

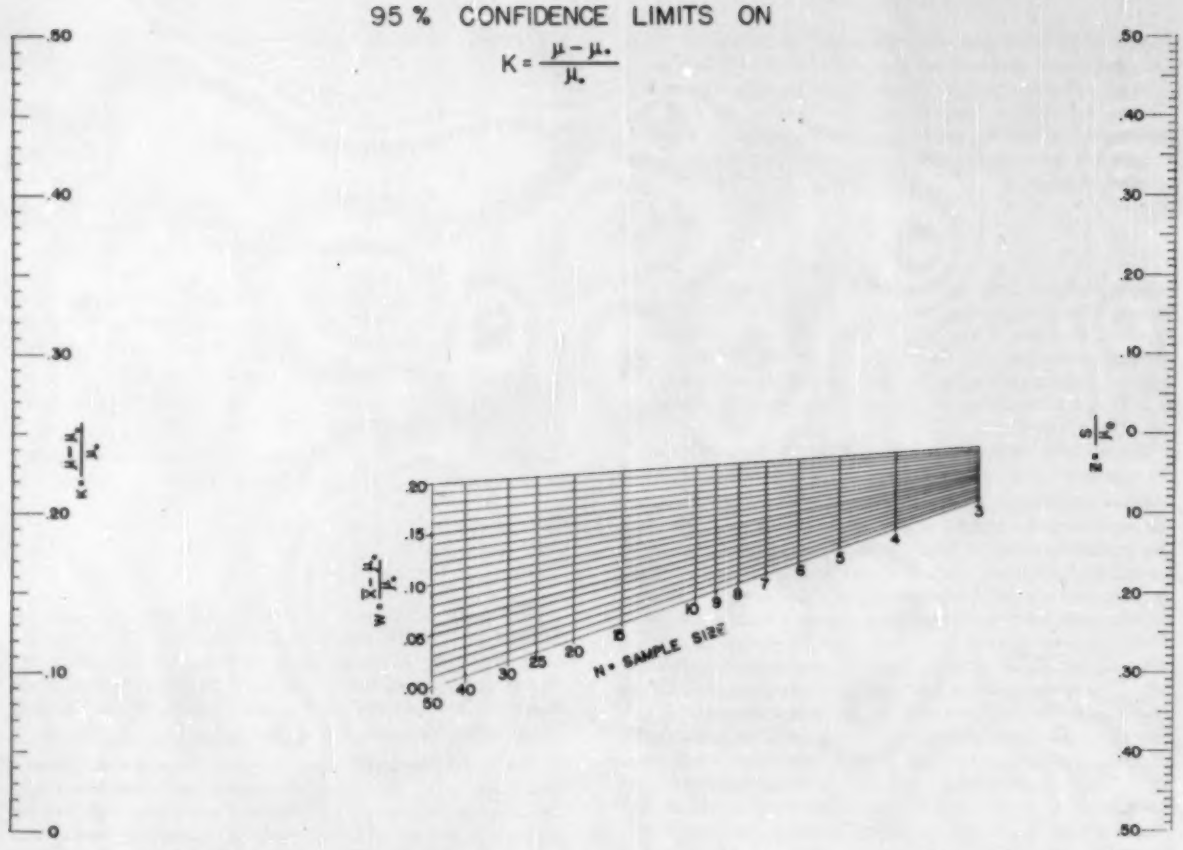
As an alternative method for those who prefer to work directly with formulas as opposed to nomograms, the

*To be more rigorous, these equations should be D = 1937 ± 0.08 (1937) and 1937 − 0.04 (1937) = 1860.

‡If w is negative, use the absolute value in the nomogram. Finally, attach the negative value to the two K-confidence limits.

95 % CONFIDENCE LIMITS ON

$$K = \frac{\mu - \mu_o}{\mu_o}$$

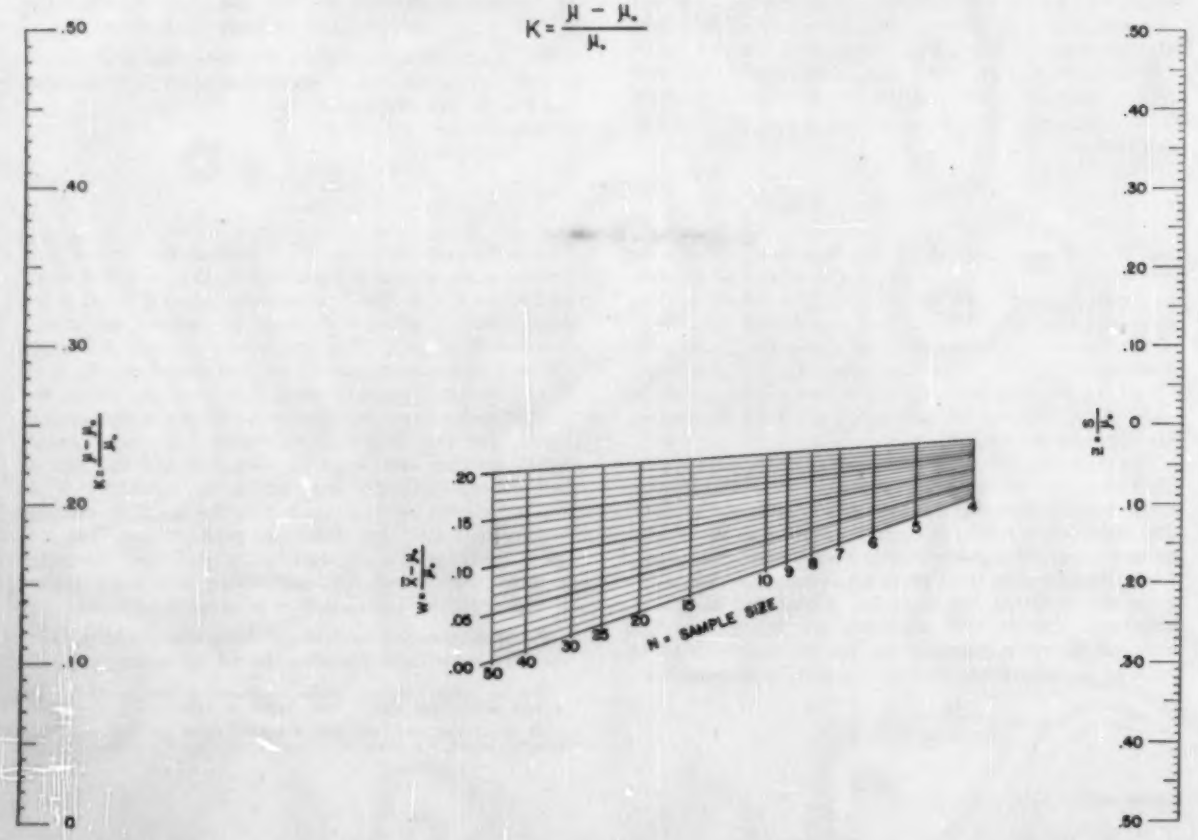


Top—Figure 2

Bottom—Figure 3

98 % CONFIDENCE LIMITS ON

$$K = \frac{\mu - \mu_o}{\mu_o}$$



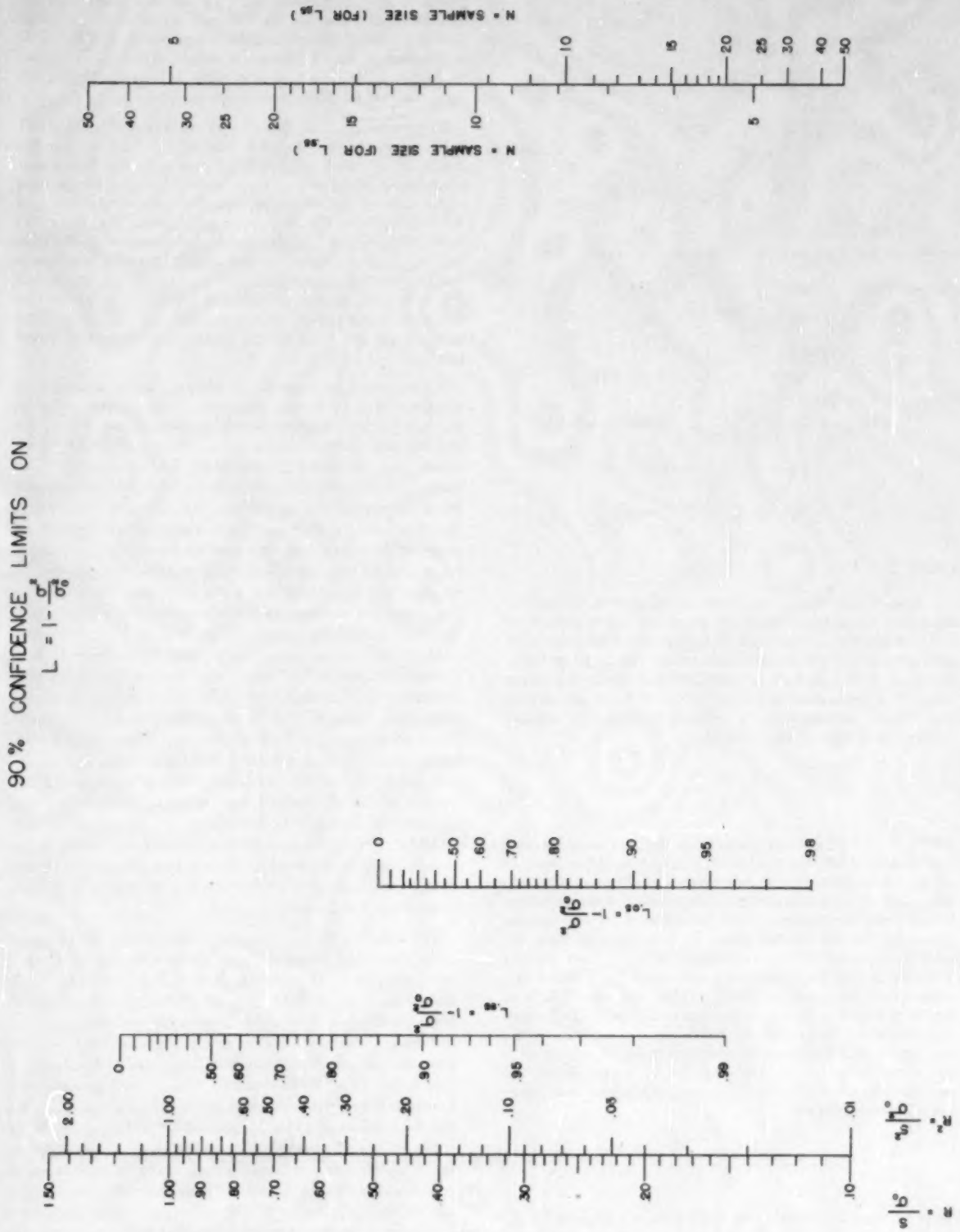

90% CONFIDENCE LIMITS ON
$L = 1 - \frac{\sigma^2}{\sigma_0^2}$
N = SAMPLE SIZE (FOR $L_{.95}$)
N = SAMPLE SIZE (FOR $L_{.95}$)
$L_{.95} = 1 - \frac{s^2}{\sigma_0^2}$
$L_{.05} = 1 - \frac{s^2}{\sigma_0^2}$
$R^2 = \frac{s^2}{\sigma_0^2}$
$R = \frac{s}{\sigma_0}$

Figure 4

example carried out above is again solved by means of formula (10) developed in the appendix.

$$\text{Given} \begin{cases} \mu_o = 1927 & S = 23 \\ \bar{X} = 19 & N = 24 \end{cases}$$

Using formula (10), namely

$$\frac{\bar{X} - \mu_o}{\mu_o} - \frac{t_{\alpha/2,N-1}}{\sqrt{N}}\left(\frac{S}{\mu_o}\right) < \frac{\mu - \mu_o}{\mu_o} < \frac{\bar{X} - \mu_o}{\mu_o} + \frac{t_{\alpha/2,N-1}}{\sqrt{N}}\left(\frac{S}{\mu_o}\right)$$

we obtain for a 95 percent confidence interval

$$\frac{1860 - 1937}{1860} - \left(\frac{2.069}{\sqrt{24}}\right)\left(\frac{23}{1860}\right) < \frac{\mu - \mu_o}{\mu_o} < \frac{1860 - 1937}{1860} + \left(\frac{2.069}{\sqrt{24}}\right)\left(\frac{23}{1860}\right)$$

$$-0.041 - 0.005 < \frac{\mu - \mu_o}{\mu_o} < -0.041 + 0.005$$

$$-0.046 < K < -0.036$$

$$\text{where } K = \frac{\mu - \mu_o}{\mu_o}$$

CASE 2

Consider now the second problem. A process for manufacturing an article has been in effect for a period of time. A change is proposed. It is suggested that this new process have a variance smaller than the present variance. In other words, it is proposed that the new process produce a more homogeneous product. A sample of size N is taken. The common χ^2 (chi-square) test of significance is carried out as follows:

$$\chi^2 = \frac{(N-1)\ S^2}{\sigma_0^2} \qquad (3)$$

where N and S^2 are the sample size and variance respectively, and σ_0^2 is the process variance which has been in effect in the past. Again, we have two alternatives: significance or non-significance, depending upon whether χ^2 exceeds the critical value determined by the sample size and the designated risk. If it is desired that the new process be 100L percent less variable than the old process, at this stage, we may still not have arrived at a conclusion for positive action. What we should like to know is whether this new process could be 100L percent less variable. Our next step in the procedure is to obtain the upper and lower confidence limits on σ^2, where σ^2 is the true variance of the population from which the sample was taken. Better still, we wish upper and lower confidence limits on

$$L = 1 - \frac{\sigma^2}{\sigma_0^2} \qquad (4)$$

This L, then, is the relative reduction in variance by the new process. Let us call the lower and upper confidence limits L_1 and L_2 respectively. Suppose a specific value of L, say L′, is required. Suppose, also, that a significant difference were obtained. Now, if L′ is less than L_1 then with, say 95 percent confidence, the new process is at least 100L′ percent less variable than the old process. Further, if L′ is greater than L_2, the new process could not (with the desired confidence) be as much as 100L′ percent less variable than the old process. Finally, if L′ is between L_1 and L_2 then we cannot arrive at an immediate conclusion and should take a larger sample, but with a financial-statistical basis for doing so.

In general, to find the $(1-\alpha)$ confidence limits on L, from nomograms 4, 5 and 6, that is $L_{\alpha/2}$ and $L_{1-\alpha/2}$ one needs N, S^2, and σ_0^2 (or N, S and σ_0). For the lower confidence limit, the sample size N is selected on the right side of the N scale and the calculated value of $R^2 = S^2/\sigma_0^2$ (or $R = S/\sigma_0$)* is selected on the R^2 (or R) scale. A straight line through these points intersects the line $L_{\alpha/2}$ (the L scale on the right). This is the lower limit. For the upper limit, R^2 (or R) is the same, but the left side of the N scale is used. A straight line through these points intersects the $L_{1-\alpha/2}$ scale (the L scale on the left) at the desired value of the upper limit.

As a particular example of utilizing these nomograms, consider the following problem: One of the steps in the fabrication of piezoelectric crystal elements involves milling the element faces on a rotary mill. The tolerances are somewhat larger than the 3σ control chart limits, which permits some spindle wear before a rotary must be torn down to replace the spindles. The range chart is used for determining a warning limit on spindle wear as well as the point when the rotary can no longer meet the tolerances. Industrial engineering devised a method for retarding the wear process. Cost analysis indicated the method to be financially acceptable if the process variability were decreased by at least nine percent. A sample of five elements was taken from each of five revolutions of the rotary and the average range was determined. The standard deviation of the method was estimated from $\hat{\sigma} = S = (\text{average range})/d_2 = 620$‡. Long term history of the old method was obtained from range charts and σ_0 similarly estimated from $\sigma_0 = (\text{average range})/d_2 = 629$. (Although the true standard deviation of the old method was unknown, the history was of sufficient length to assume it to be equal to σ_0.) Clearly, there is no statistical difference between process capabilities, but are the 95 percent confidence limits about the relative decrease such as to warrant further expenditure of funds?

The solution to this class of problem may be obtained from Figures 4, 5 and 6. In this example, the confidence level desired is 95 percent. Hence, Fig. 5 will be used. Calculate $S/\sigma_0 = 0.99$. Draw a line from $N_{0.025} = 25$ through $S/\sigma_0 = 0.99$. The intersection of this line and the R scale provides the lower limit on the relative decrease of variability on the $L_{0.025}$ scale. Similarly, a line from $N_{0.975} = 25$ through $S/\sigma_0 = 0.99$ provides the maximum relative decrease on the $L_{0.975}$ scale. These values are found to be $L_{0.975} = 0.40$ and $L_{0.025} < 0$. In other words, the sample value is such that a decrease as large as 40 percent may occur, while it may also be possible that there is actually an increase in element variability. In this particular situation, it was decided to continue experimentation, since the potential decrease was large relative to the desired minimum decrease.

*The R used here represents a ratio, not a sample range.

‡Coded value.

95 % CONFIDENCE LIMITS ON
$L = 1 - \frac{\sigma^2}{\sigma_0^2}$
N = SAMPLE SIZE (FOR $L_{.975}$)
N = SAMPLE SIZE (FOR $L_{.025}$)
$L_{.975} = 1 - \frac{\sigma^2}{\sigma_0^2}$
$L_{.025} = 1 - \frac{\sigma^2}{\sigma_0^2}$
$\frac{\sigma^2}{\sigma_0^2}$
$\frac{\sigma}{\sigma_0}$

Figure 5

98 % CONFIDENCE LIMITS ON
$L = 1 - \frac{\sigma^2}{\sigma_0^2}$
N = SAMPLE SIZE (FOR $L_{.99}$)
N = SAMPLE SIZE (FOR $L_{.01}$)
$L_{.01} = 1 - \frac{\sigma^2}{\sigma_0^2}$
$L_{.99} = 1 - \frac{\sigma^2}{\sigma_0^2}$
$R = \frac{s}{\sigma_0}$
$R^2 = \frac{s^2}{\sigma_0^2}$

Figure 6

As an alternative method without the use of nomograms, consider formula (16) developed in the appendix.

Given

$S/\sigma_0 = 0.99$ $\qquad$ $\chi^2_{\alpha/2,24} = 12.400$

$N = 25$ $\qquad$ $\chi^2_{1-\alpha/2,24} = 39.364$

Using equation (16) in the appendix, we have

$$1 - \left(\frac{S^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{\alpha/2,N-1}} < 1 - \frac{\sigma^2}{\sigma_0^2} < 1 - \left(\frac{\sigma^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{1-\alpha/2,N-1}}$$

For 95 percent confidence this becomes

$$1 - (0.98)\frac{24}{12.400} < 1 - \left(\frac{\sigma^2}{\sigma_0^2}\right) < 1 - (0.98)\left(\frac{24}{39.364}\right)$$

$$-0.90 < L < 0.40$$

where $L = 1 - \frac{\sigma^2}{\sigma_0^2}$ and -0.90 indicates that there could actually be a sizeable increase in variance.

CASE 3

Suppose two processes are proposed for a new product. There is no question that either process can meet the requirement for the population mean. The only question is, "Which of the two processes is less variable?" Suppose a sample were taken from each of the processes. The common test of significance between variances is performed using the statistic:

$$F = \frac{S_1^2}{S_2^2}, \qquad (5)$$

the S^2's being the sample variances. Again, a conclusion of significance or non-significance is not sufficient if it is desired that one process be at least 100K percent less variable than the other. What is required is the confidence limits on σ_1^2/σ_2^2 where σ_1^2 is the true variance of the population from which the sample with the larger variance came, and σ_2^2 is the other population variance. Suppose we wish, rather, the ratio of σ_1^2 to σ_2^2:

$$K = \frac{\sigma_1^2}{\sigma_2^2} \qquad (6)$$

A particular K, say K', is specified as a minimum value. Further, K_1 and K_2 are lower and upper confidence limits respectively on K. If K' is less than K_1, then we can draw the conclusion on the basis of the specified confidence that one process is at least 100K' percent of the other in variance. If, on the other hand, K' is greater than K_2 then regardless of whether the F-test showed significance, we cannot, on the basis of our samples, say one process is at least 100K' percent of the other. Finally, if K' is between K_1 and K_2 we should consider a larger sample.

Due to the number of variables involved, there are two nomograms for each confidence level, one for the upper bound on the ratio of variance, and one for the lower bound. On all nomograms, find the point (N_1,N_2) on the right hand grid. Calculate $Q = S_1^2/S_2^2$ (with $S_1^2 > S_2^2$) and obtain the point (N_1,Q) on the left hand grid. On nomograms 7, 9 and 11 the intersection of the line between the grids and the K scale provides the lower limit of the ratio σ_1^2/σ_2^2, while on nomograms 8, 10 and 12 the point on the K scale is the upper limit of the ratio.

As an example of the use of these nomograms, consider the following situation: Two different products use similar pressure switches, each at a different pressure level, one at about 220 psi and the other at 330 psi. It would be desirable to use the same control chart for all switches, simply measuring the deviations from nominal. To do this, the standard deviations about each nominal must be the same. On the basis of various criteria it was determined that "equal" would be defined as a maximum difference of 5.77 percent. Forty-six switches were tested at each of the two levels. The standard deviations of pressure differential were calculated to be:

S (level I) $= 5.536 = S_2$

S (level II) $= 5.710 = S_1$

$S_1/S_2 = 1.031$; $Q = S_1^2/S_2^2 = 1.06$

Does the difference of 3.10 percent indicate that the true difference will be less than the maximum permissible at the 95 percent confidence level? Utilizing the standard test of significance, $S_1^2/S_2^2 < F_{0.95,45,45} = 1.65$, so there is no statistical difference between the two variances. This does not tell us, however, that the difference between the two variances is less than 5.77 percent. Figures 7 through 12 can be utilized to solve this type of problem. For this particular example, enter the right hand grid of Fig. 9 at the point $N_1 = N_2 = 46$, the left hand grid at the point ($N_1 = 46$, $Q = 1.06$). The intersection of the line between the two points and the K scale at $K = 0.6$ gives the lower limit on the ratio of the variances. Similarly, from Fig. 10, $K = 1.9$ gives the upper limit on this ratio. This indicates that the true ratio of variances may be anywhere from 0.6 to 1.9. As a result, it was decided to use two control charts until more data were accumulated, since the true ratio may be greater than the maximum permissible.

As an alternative method without the use of nomograms, consider formula (20) which is developed in the appendix.

Given

$S_1/S_2 = 1.031$ $\qquad$ $F_{0.975,45,45} = 1.81$

$N_1 = N_2 = 46$ $\qquad$ $F_{0.025,45,45} = 1/1.81 = 0.55$

Using formula (20) with $Q = 1.06 = S_1^2/S_2^2 > 1$

$$\frac{Q}{F_{1-\alpha/2,N_1-1,N_2-1}} < \frac{\sigma_1^2}{\sigma_2^2} < \frac{Q}{F_{\alpha/2,N_1-1,N_2-1}}$$

$$(1.06)\ (0.55) < \sigma_1^2/\sigma_2^2 < (1.06)\ (1.81)$$

$$0.58 < K < 1.92$$

where $K = \sigma_1^2/\sigma_2^2$.

Conclusion

The reader should realize that the foregoing examples are illustrative only and that the methods are generally applicable to significance tests. Further, we believe that the greatest value to be derived comes from the ability of the statistician to attach a rather firm dollar sign to his conclusions, thus speaking management's language. Less important, but perhaps more satisfying to the statistician, is the ability to make positive assertions even in the case of non-significance, thus eliminating vagueness.

Acknowledgment

The authors are indebted to Dr. Orley E. Brown for invaluable assistance in the design of the nomograms contained in this article.

(The Appendix follows Figures 7-12 and begins on page 20.)

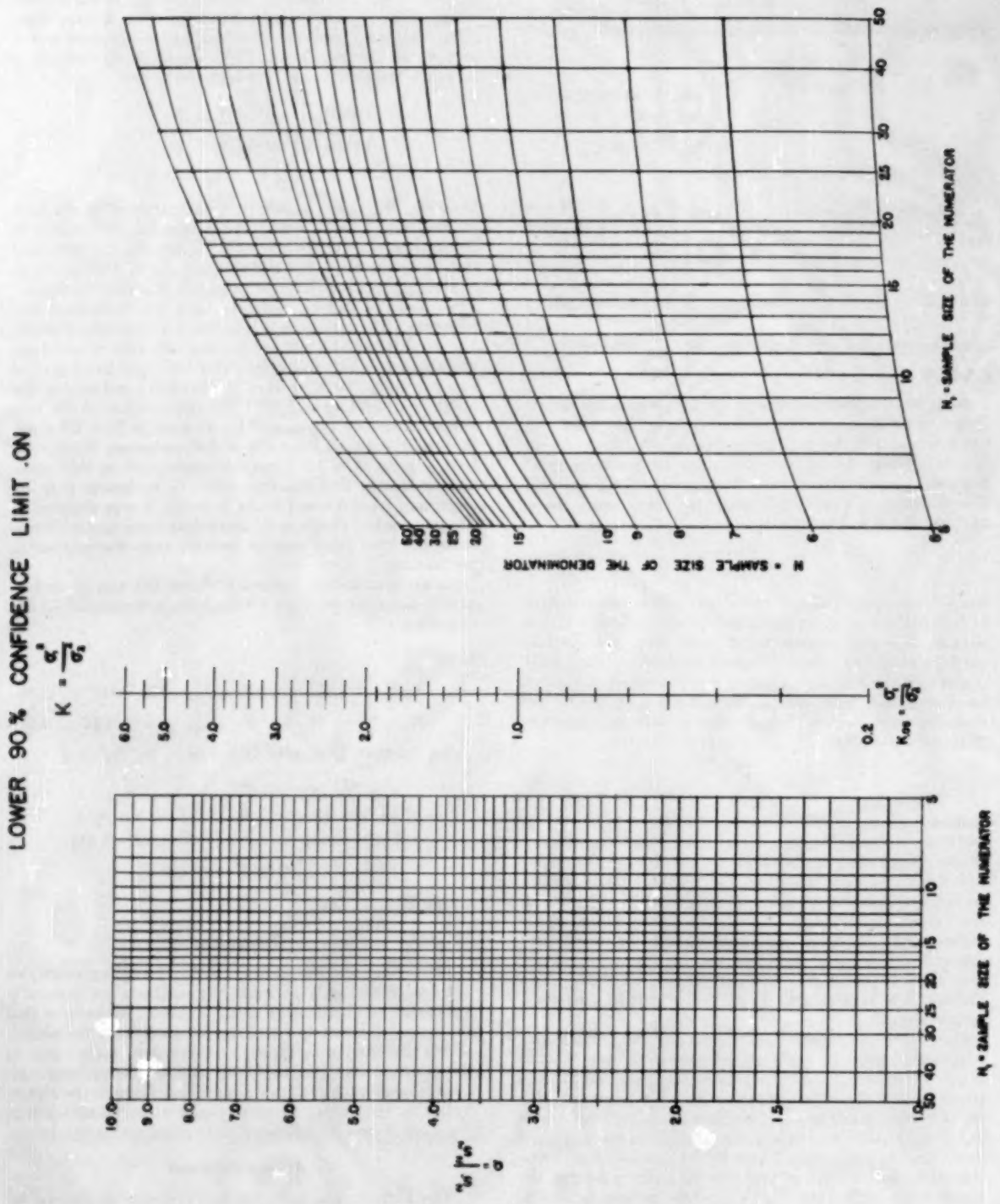

LOWER 90 % CONFIDENCE LIMIT ON
$K = \frac{\sigma'}{\sigma_0}$
N = SAMPLE SIZE OF THE DENOMINATOR
N_1 = SAMPLE SIZE OF THE NUMERATOR
$K_{90} = \frac{\sigma'}{\sigma_0}$
$\rho = \frac{s'}{s}$
N_1 = SAMPLE SIZE OF THE NUMERATOR

Figure 7

UPPER 90% CONFIDENCE LIMIT ON

$K = \frac{\sigma_1^2}{\sigma_2^2}$

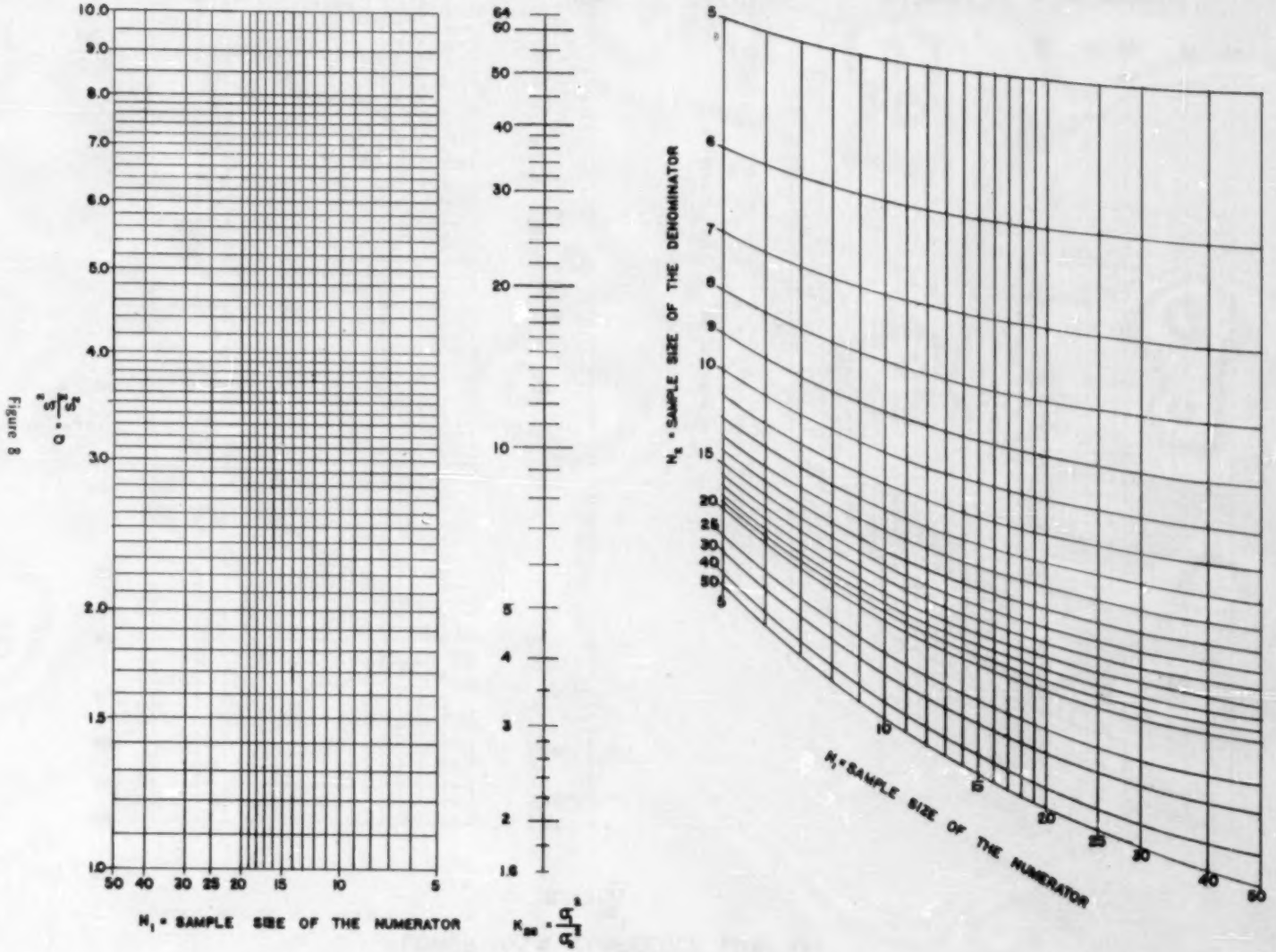


Figure 8

LOWER 95% CONFIDENCE LIMIT ON

$$K = \frac{\sigma_1^2}{\sigma_2^2}$$

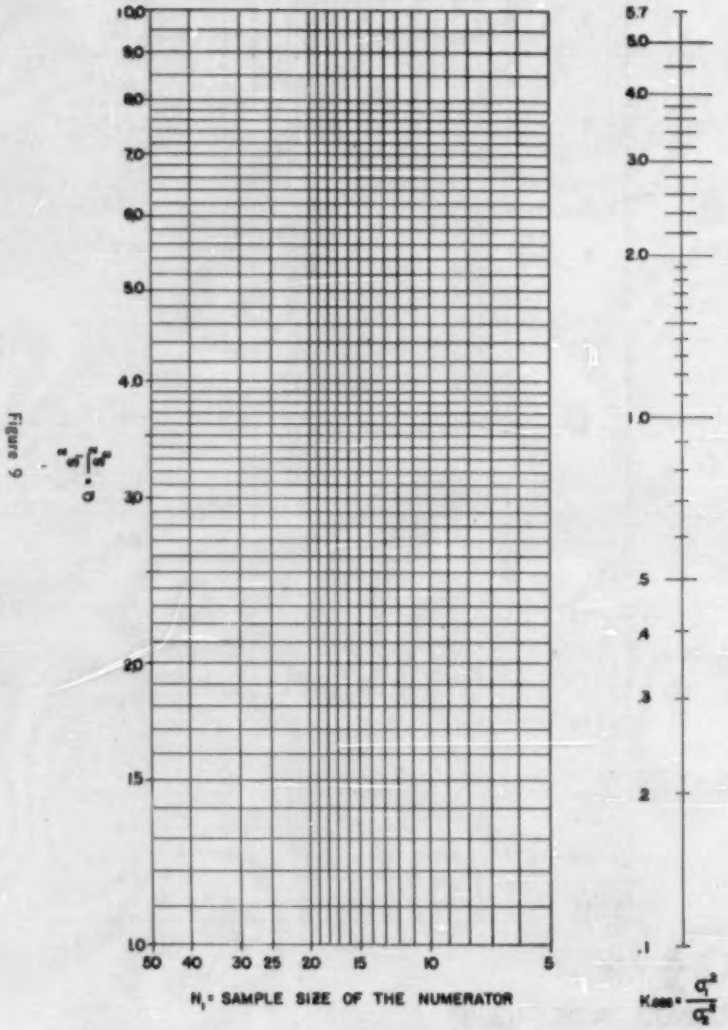
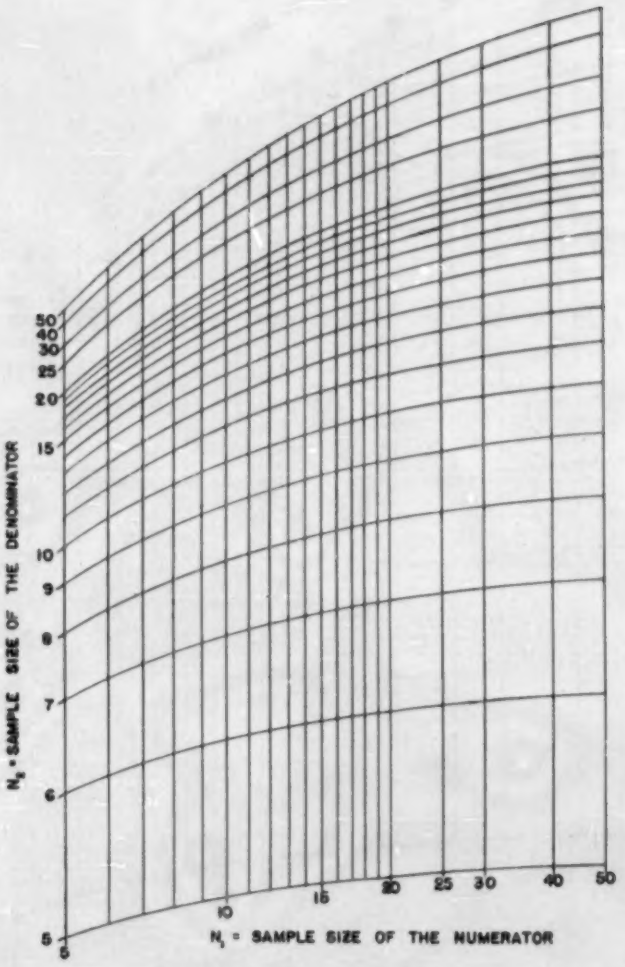


Figure 9



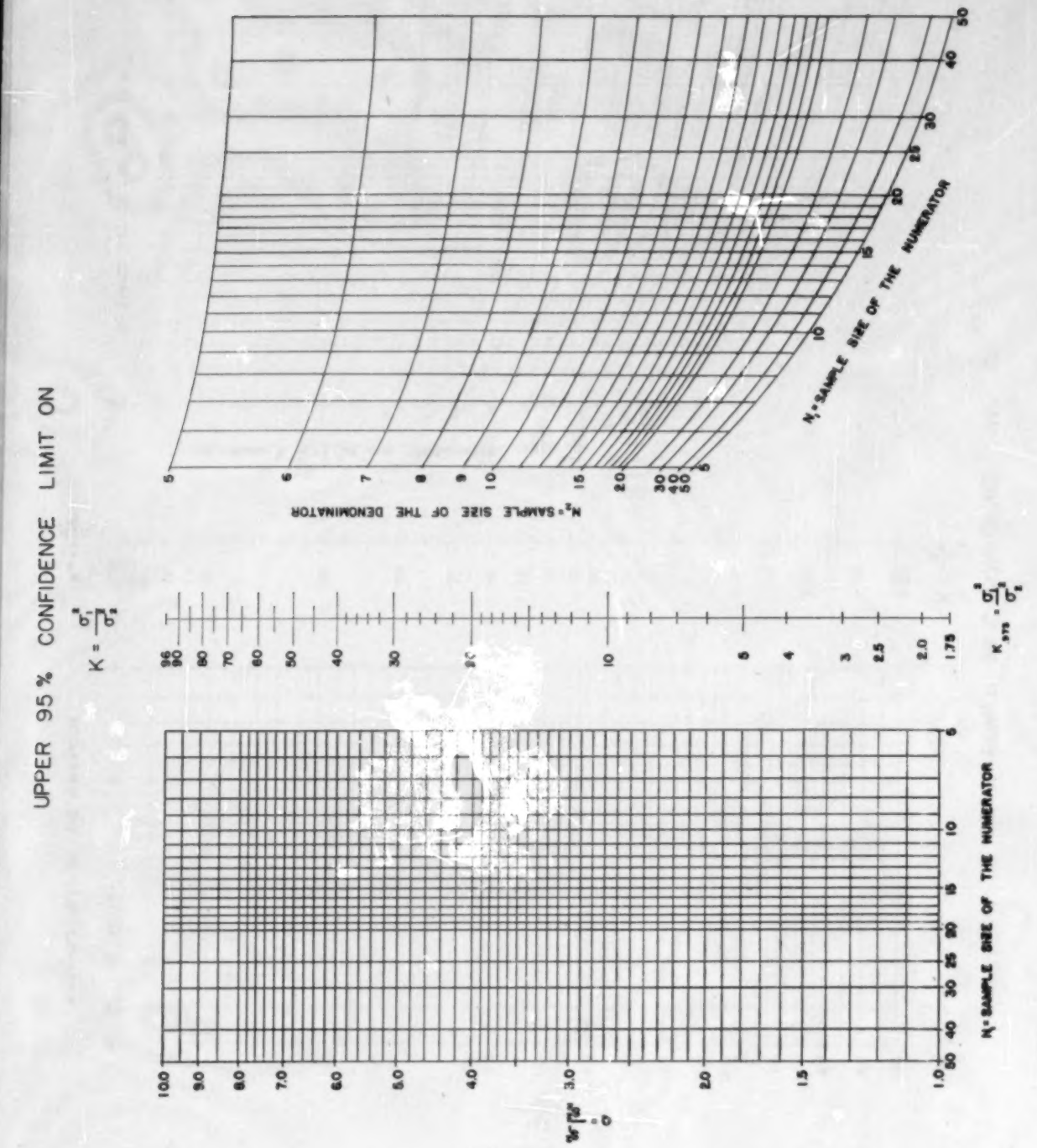

UPPER 95 % CONFIDENCE LIMIT ON
$K = \frac{\sigma_1^2}{\sigma_2^2}$
N_2 = SAMPLE SIZE OF THE DENOMINATOR
N_1 = SAMPLE SIZE OF THE NUMERATOR
$K_{.95} = \frac{S_1^2}{S_2^2}$
N_1 = SAMPLE SIZE OF THE NUMERATOR
$\frac{S_1^2}{S_2^2} = 0$

Figure 10

LOWER 98 % CONFIDENCE LIMIT ON

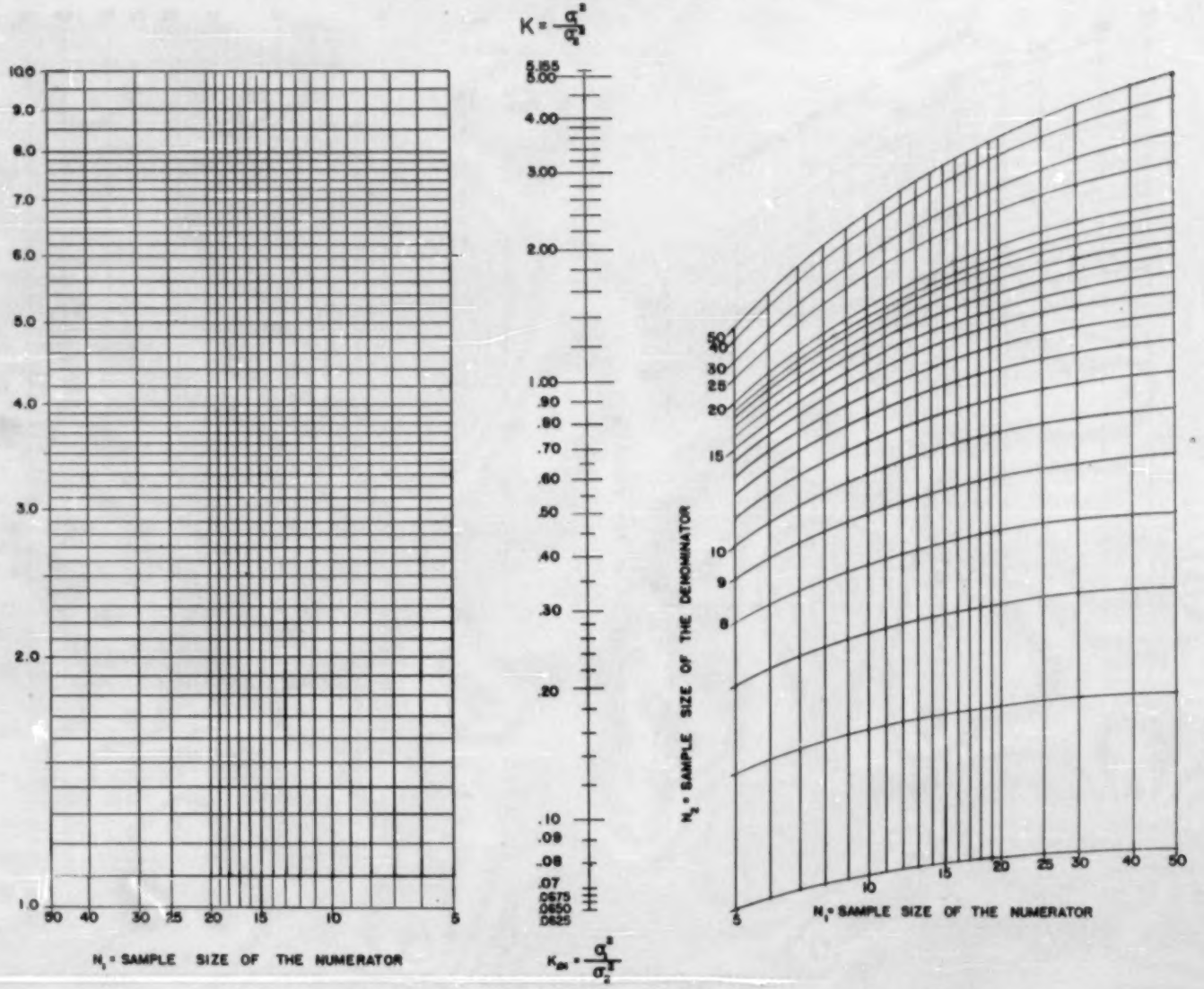


Figure 11

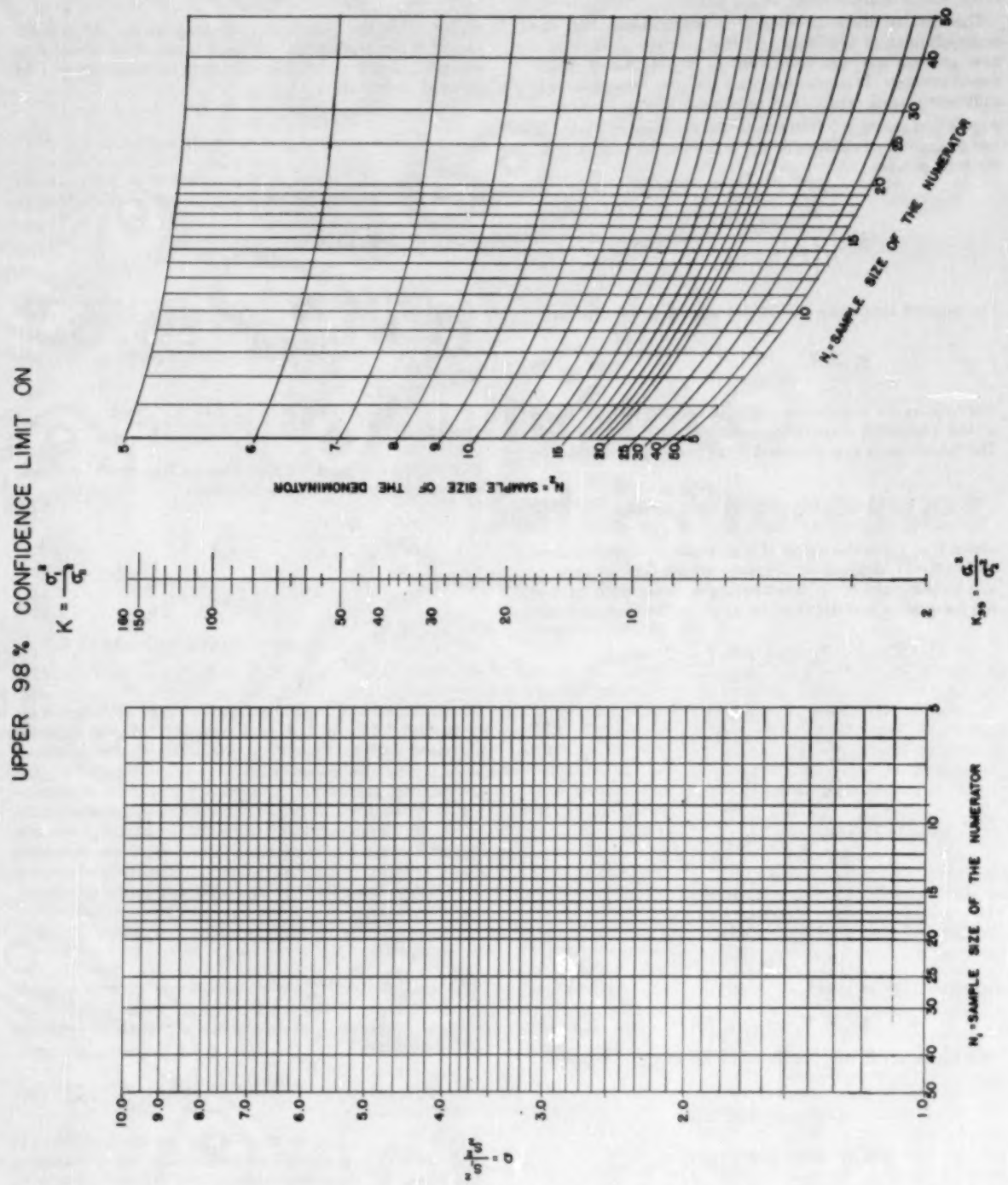

UPPER 98 % CONFIDENCE LIMIT ON
$K = \frac{\sigma_1^2}{\sigma_0^2}$
N_2 = SAMPLE SIZE OF THE DENOMINATOR
N_1 = SAMPLE SIZE OF THE NUMERATOR
$K_{98} = \frac{s_1^2}{\sigma_0^2}$
$= \frac{s_1^2}{\sigma_0^2} \div 0$

Figure 12

Appendix

The problems presented in this article may be classified into three categories. Essentially, each case involves the determination of the $(1-\alpha)$ confidence limits on a ratio, where α is the error of the first kind.

The first of these problems concerns itself with the establishment of the limits on the relative change of a new process average from that of a previously established process. It is assumed that the previous process is sufficiently well established to provide the parameter of population mean, μ_o. Determine the estimate of mean, $\bar{X}$, and standard deviation, S, by a sample of size N from the new process, where

$$S = \left\{ \frac{\sum_{i=1}^{N} (X_i - \bar{X})^2}{N-1} \right\}^{\frac{1}{2}} \tag{7}$$

The desired limits are the $(1-\alpha)$ confidence limits on

$$K = \frac{\mu - \mu_o}{\mu_o} \tag{8}$$

where μ_o is the population mean of the old process and μ is the unknown population mean of the new process. The limits on μ are obtained from the t distribution by

$$\bar{X} - \frac{S}{\sqrt{N}} t_{\alpha/2,N-1} < \mu < \bar{X} + \frac{S}{\sqrt{N}} t_{\alpha/2,N-1} \tag{9}$$

where $t_{\alpha/2,N-1}$ is the value of t in Student's t distribution with $(N-1)$ degrees of freedom which has an area of $\alpha/2$ to the right of it. Subtracting μ_o from each part of the inequality and dividing by μ_o gives the desired limits

$$\frac{\bar{X}-\mu_o}{\mu_o} - \frac{t_{\alpha/2,N-1}}{\sqrt{N}}\left(\frac{S}{\mu_o}\right) < \frac{\mu-\mu_o}{\mu_o} < \frac{\bar{X}-\mu_o}{\mu_o} + \frac{t_{\alpha/2,N-1}}{\sqrt{N}}\left(\frac{S}{\mu_o}\right) \tag{10}$$

Letting $w = \dfrac{\bar{X}-\mu_o}{\mu_o}$

$$A = \frac{t_{\alpha/2,N-1}}{\sqrt{N}}$$

$$Z = S/\mu_o$$

$$K = \frac{\mu-\mu_o}{\mu_o}$$

equation (10) becomes

$$w - AZ < K < w + AZ \tag{11}$$

The limits on K may be determined in Figs. 1, 2 and 3 for

$$\alpha = 0.02,\ 0.05,\ 0.10,$$

$$3 \leq N \leq 50 \text{ and } 0 \leq w \leq 20$$

The second problem concerns itself with the establishment of the limits on the relative change of a new process variance from that of a previously established process. It is assumed that the history of the previous process is of sufficient length to provide the parameter of population variance, σ_0^2. Determine the estimate of the variance, S^2, by a sample of size N from the new process. The desired limits are the $(1-\alpha)$ confidence limits on

$$L = \frac{\sigma_0^2 - \sigma^2}{\sigma_0^2} = 1 - \frac{\sigma^2}{\sigma_0^2} \tag{12}$$

where σ_0^2 is the population variance of the old process and σ^2 is the population variance (unknown) of the new process. Limits on σ^2 may be obtained from the χ^2 (chi square) distribution

$$\chi^2_{\alpha/2,N-1} < \frac{(N-1)\ S^2}{\sigma^2} < \chi^2_{1-\alpha/2,N-1} \tag{13}$$

where $\chi^2_{\alpha/2,N-1}$ refers to that value of χ^2 with $(N-1)$ degrees of freedom which has $\alpha/2$ area to the left of it.

Multiplying through by $\dfrac{\sigma_0^2}{(N-1)\ S^2}$

$$\left(\frac{\sigma_0^2}{S^2}\right)\frac{\chi^2_{\alpha/2,N-1}}{N-1} < \frac{\sigma_0^2}{\sigma^2} < \left(\frac{\sigma_0^2}{S^2}\right)\frac{\chi^2_{1-\alpha/2,N-1}}{N-1} \tag{14}$$

Taking the reciprocal and therefore reversing inequalities, (14) becomes

$$\left(\frac{S^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{\alpha/2,N-1}} > \frac{\sigma^2}{\sigma_0^2} > \left(\frac{S^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{1-\alpha/2,N-1}} \tag{15}$$

Subtract each part of the inequalities from one and again reverse inequalities to obtain

$$1 - \left(\frac{S^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{\alpha/2,N-1}} < 1 - \frac{\sigma^2}{\sigma_0^2} < 1 - \left(\frac{S^2}{\sigma_0^2}\right)\frac{N-1}{\chi^2_{1-\alpha/2,N-1}} \tag{16}$$

Inequality (16) then gives the desired limits on L:

$$L_{\alpha/2} < L < L_{1-\alpha/2} \tag{17}$$

These limits may be determined by Figs. 4, 5, and 6 for $\alpha = 0.02,\ 0.05$ and 0.10 and $5 \leq N \leq 50$. Where the standard deviation is used in lieu of the variance, values of S/σ_0 are also given.

The third category of problems concerns the determination of the least variable of two new processes. Estimates of the population variances S_1^2 and S_2^2 are obtained from samples of size N_1 and N_2 from processes 1 and 2 respectively. The estimate of the "better" process is obtained from the $(1-\alpha)$ confidence limits on

$$K = \frac{\sigma_1^2}{\sigma_2^2} \tag{18}$$

where σ_1^2 is the population variance of process 1, σ_2^2 is the population variance of process 2 and $S_1^2 > S_2^2$. Confidence limits on a ratio similar to equation (18) are obtained from

$$F_{\alpha/2,N_1-1,N_2-1} < \frac{S_1^2/\sigma_1^2}{S_2^2/\sigma_2^2} < F_{1-\alpha/2,N_1-1,N_2-1} \tag{19}$$

where $F_{\alpha/2,N_1-1,N_2-1}$ is that value of F with (N_1-1) and (N_2-1) degrees of freedom which has $\alpha/2$ area to the left of it. Very few tables of the F distribution give $F_{\alpha/2,N_1-1,N_2-1}$ where $\alpha/2$ is less than 0.50. For, say $\alpha/2 = 0.025$, the procedure is to obtain $F_{0.975,N_2-1,N_1-1}$, and then use the identity

$$F_{0.025,N_1-1,N_2-1} = \frac{1}{F_{0.975,\ N_2-1,N_1-1}}$$

Finally by multiplying (19) through by S_2^2/S_1^2 and taking the reciprocal, we get

$$\frac{Q}{F_{1-\alpha/2,N_1-1,N_2-1}} < \frac{\sigma_1^2}{\sigma_2^2} < \frac{Q}{F_{\alpha/2,N_1-1,N_2-1}} \qquad (20)$$

where $Q = S_1^2/S_2^2 > 1$. Simplifying this, one obtains

$$\frac{Q}{F_{1-\alpha/2,N_1-1,N_2-1}} < \frac{\sigma_1^2}{\sigma_2^2} < Q\,F_{1-\alpha/2,N_2-1,N_1-1}. \qquad (21)$$

As a simple illustration of this last case with $N_1 \neq N_2$, consider the problem presented earlier:

$S_1/S_2 = 1.031$ but $N_1 = 15$, $N_2 = 20$; also, $Q = 1.06$.

For $\alpha = 0.05$, inequality (20) gives us

$$\frac{1.06}{F_{0.975,14,19}} < \frac{\sigma_1^2}{\sigma_2^2} < \frac{1.06}{F_{0.025,14,19}}$$

Then

$$\frac{1.06}{F_{0.975,14,19}} < \frac{\sigma_1^2}{\sigma_2^2} < (1.06)F_{0.975,19,14}$$

and finally

$$\frac{1.06}{2.65} < \frac{\sigma_1^2}{\sigma_2^2} < (1.06)\ (2.86)$$

$$0.40 < \frac{\sigma_1^2}{\sigma_2^2} < 3.03.$$

Control Charts in Multi-Stage Batch Processes*

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Application of statistical control in the chemical process industry has been hampered partly by lack of understanding of how statistical concepts may be applied to advantage beyond that commonly gained with standard chemical analyses and physical tests. Renner[17] has pointed out reasons for reluctance among chemists to adopt statistical control tenets, while Bicking[2,3,4], Wernimont[20], and Hader & Youden[12] have discussed scores of problems solvable with the techniques. This article reviews underlying concepts of statistical control as applied to batch chemical processes. A study of spent acid reduction in a countercurrent 3-stage nitration process illustrates some of the principles.

Interpretation of Concepts for Batch Control

In the chemical industry, or any other field, no control is valid unless it means regulation within important, technically selected limits. In most cases, the limits are pre-set from background knowledge to meet customer requirements, or from economic restrictions; but process capability may be the governing factor. The limits must be set to reflect deviations associated with departures from standard operating procedures of practical importance, and not to call attention to fluctuations in raw materials, operating conditions, or operator manipulations within the allowable range. Limit exceedances call for corrective action—adjustment of the process, recycle or reworking of the material under reaction. For batch processes, other prerequisites of the "statistical control" concept such as observation order, randomness, and rational subgrouping, are incorporated in the sampling and charting instructions peculiar to each situation. Justification for chart control includes recognition that the technique provides psychological as well as technical advantages for guiding operations, whether these processes include raw material acceptance, manufacturing, laboratory analysis, product verification, or experimentation. Although the chemical phase of processing control is generally the main consideration, attention to physical entities like time cycles, ingredient weights, and equipment calibration reduces chance variation, further increasing detection sensitivity.

Types of Batch Control

The type of batch control used depends on technical knowledge of the process and available tests. Charges may be considered individually or treated as parts of a larger semi-continuous process. "Within-batch" control may utilize charts to follow a reaction to an end point. A regression line and limits generally replace the conventional central line[14]. The trend chart of Fig. 1 shows a typical case. Specifically, individual results taken over the time period of interest are plotted against the given line and its 2-σ limits. For good power, the test method must be quick compared to the batch cycle, and possess high reproducibility. If the batch is to be "cooked" to reach a given end point, thus influencing cycle time, the method is limited to single-vessel

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reactions and co-current flow sequences.

"Batch-to-batch" control[13] treats successive charges as parts of a continuous procedure in which restraints on operator methods, chemical variables, and producing conditions assure reproducibility. Although making good batches remains the goal, the guiding philosophy makes use of information from *preceding* batches for control of processing conditions for *succeeding* charges. Operator aids in the form of instrumentation and chart control must be provided to avoid assignable causes from the human element. As in "within-batch" control, single samples from well-mixed vessels of liquids or gases may be compared on control charts for individuals. Choice of probability factors depends on power needed; but 2-σ limits for individuals and moving range charts, combined with run theory, seem adequate for many situations[19]. If test methods are too variable, replicate tests on the same sample may be needed for adequate precision[1]. Solids or aggregates of various sizes may require a detailed sampling plan to give representative results[15]. The control chart for individual batch results follows changes in the process average for batches made under the same conditions. The moving range chart detects increases or decreases in batch-to-batch uniformity, trends, and serial correlation (see Fig. 1). The relative insensitivity of the individual batch chart compared with an average chart for detecting shifts in average can be overcome by proper choice of control limits and sampling frequency, often limited to one sample per batch. Moving averages over several batches may be used where the analogy to physical compositing seems appropriate. Generally, converging parallel process streams with subsequent common treatment or counter-current stepwise flow practices are suited to "batch-to-batch" type control.

A Decision for Chart Control

Chemists and chemical engineers have provided process control *without control charts* by using instrumentation, operator log sheets, chemical analyses, and physical tests. To justify chart control, convincing arguments must be presented citing advantages of graphic presentation, action limits for operators, rapid detection of improvements or losses, awareness of trends or changes in variability, and ease of correlation of processing variables. The continual comparison of "what the process is doing" with its capability or established standards is likely to be most rewarding. The achievement of greater product uniformity by the elimination of unnecessary processing adjustments, commonly made by shift crews when taking over the shift, helps to pay the cost of control. Tighter control of trace impurities and complex chemical reactions will strengthen the case for chart control[7,9,11].

Control of Multi-Stage Processes

Multi-stage processes frequently have an additional level of complexity from the viewpoint of control. Usually, the process involves raw material additions at several stages, changes of state, and reaction in a variety of equipment; all of which may influence control. In co-current flow, control at early stages allows corrective action in subsequent steps, providing processing conditions are favorable. A continuous check on product quality is possible by following a particular batch from stage to stage observing various checkpoint results.

In counter-current flow, process information must travel both directions for control. In many cases, where isomer formation or yield is influenced by operating conditions at each of the various steps, control of reactants must be accomplished at each stage even though over-all chemical "balance" is maintained. Considering the method of operation it is not surprising to find that control of a particular batch in the later stages of the process eventually produces control of a batch six or seven steps behind. Thus, every batch has a complex but traceable history. (This is in contrast to a truly random batch operation in which a given batch is completely independent of any previous batch.) These characteristics emphasize the continuous nature of the process over

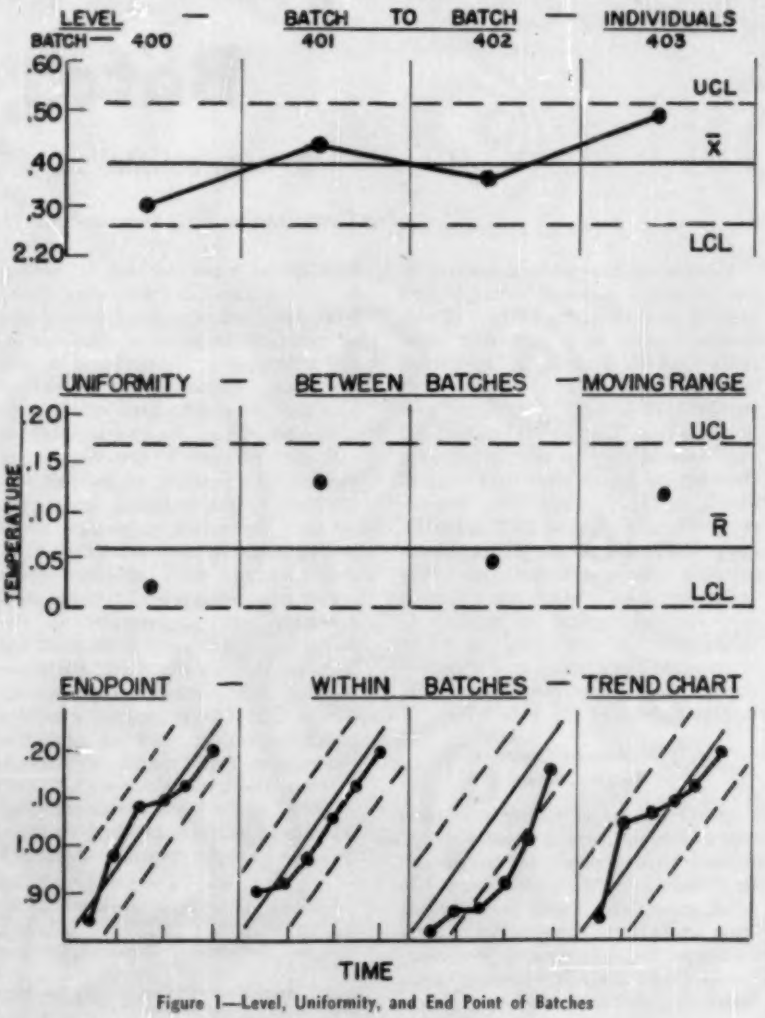

Figure 1—Level, Uniformity, and End Point of Batches

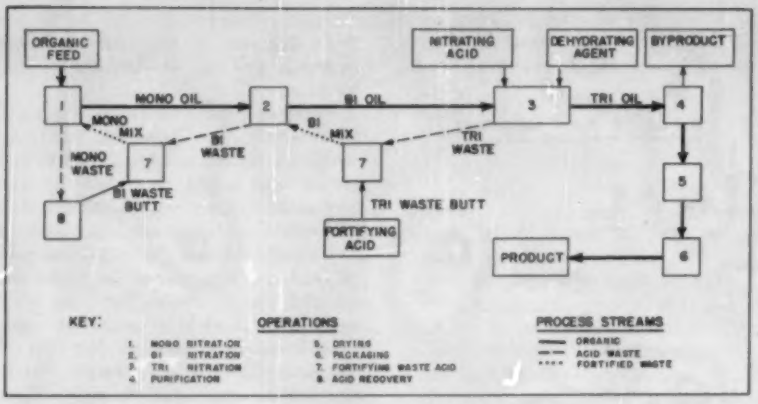

Figure 2—Process Flow Sheet

that of the individual batches. It should be realized that in many cases the continuous process corresponding to the multi-step batch process is a limit to be approached more closely as control improves. The physical analogy to this comparison is apparent since many batch processes would be continuous processes if economics, equipment design, available equipment, or reaction kinetics permitted.

An Example

The principles described may be illustrated with some data taken on a three-stage batch nitration process using counter-current flow of nitrating acid and organic[8,10,18]. The material flow is shown in Fig. 2. Acid concentrations, temperatures, and reaction times are necessarily increased as the nitration adds additional "nitro" groups to the organic molecule. Waste acid from the "tri" stage is strengthened with additional acid (called "tri waste butt") to make a "bi mix", which is used in the "bi" nitration. Also, "bi waste acid" is fortified with additional acid (called "bi waste butt") to make a "mono mix" which is used as the nitrating agent in the "mono" nitration. The "mono waste acid" is sent to a recovery plant where the components are separated and strengthened. One of the components is used as fortifying acid for the bi waste acid to make the mono mix. The product from each nitration stage is referred to as an "oil"; mono oil, bi oil and tri oil. Routine control of the process covers product quality, yield, reactant use, reactant recovery, and acid strength.

From a review of production records, the operating department decided that the amount of nitrating acid charged per batch and hence, the amount to be recovered could be reduced with a resultant saving in reactant and possible increase in plant capacity. Calculations were made by the technical department to determine the desired operating point. The amount of nitrating acid to strengthen the bi waste was reduced for one production line during a ten-day plant trial. After successful results for two days, the same procedure was instituted on other production lines. Several days later, the operating department reported that the yield was dropping. The test was halted and in light of the apparent yield loss, a data analysis was requested to evaluate whether the desired reduction had been achieved, whether the test was sufficient to preclude the reduction as a realistic possibility again, how much the yield had been reduced, and any other relations among the variables measured.

Since the plant test had been carried out without control charts as guides, the batch to batch behavior was not immediately obvious. Also, yield data on a batch basis were not considered as reliable, for estimating the average yield and its fluctuation, as yield data covering each day. Since composite samples of mono waste rather than individual batch samples had been collected and chemically analyzed, a further restriction was imposed on the subsequent data analysis. Lacking complete batch information, so that daily averages and within day range charts could not be prepared, it was necessary to resort to plotting daily averages as individual measurements for each of the measured variables. The moving range estimated the day to day variation. Control limits for the individual batch and moving range charts were calculated from the average and standard deviation for each of the two time periods—"pre-test" and "test". (These 2-σ confidence limits were shown on the

TABLE I—Regression and Control Chart Evaluation

Regression

Variables		Data		Percent of Variance Explained	Equation Slope
Dependent	Independent	Pre-test	Pre-test & Test		
x_5 (mono waste strength)	x_3 (bi waste butt weight)		***	81	0.00449
x_1 (mono oil weight)	x_3 (bi waste butt weight)		**	39	0.142
x_2 (bi oil weight)	x_1 (mono oil weight)	**		90	0.948
y (yield)	x_2 (bi waste butt weight)	* #		73	—0.244

Control Charts

Chart	Property	Change in Average	Comments
x_1	mono oil weight	*	Trend before plant test
x_2	bi oil weight		Trend before plant test
x_3	bi waste butt weight	*	
x_4	tri waste butt weight		
x_5	mono waste strength	**	
y	yield		

Significance Levels: * (0.05) ** (0.01) *** (0.001)

Over the pre-test period this equation would be:

$$y - \bar{y} = -0.206(x_1 - \bar{x}_1) + 0.280(x_2 - \bar{x}_2) - 0.244(x_3 - \bar{x}_3) - 0.156(x_4 - \bar{x}_4)$$

See Table III for calculations. (Data have been coded.)

charts even though insufficient points were present to establish standard limits; and lack of control was noted in the form of trends, runs, and single points out of control.) Confidence limits for the averages and variances were calculated using the true degrees of freedom to judge shifts in average or changes in dispersion.

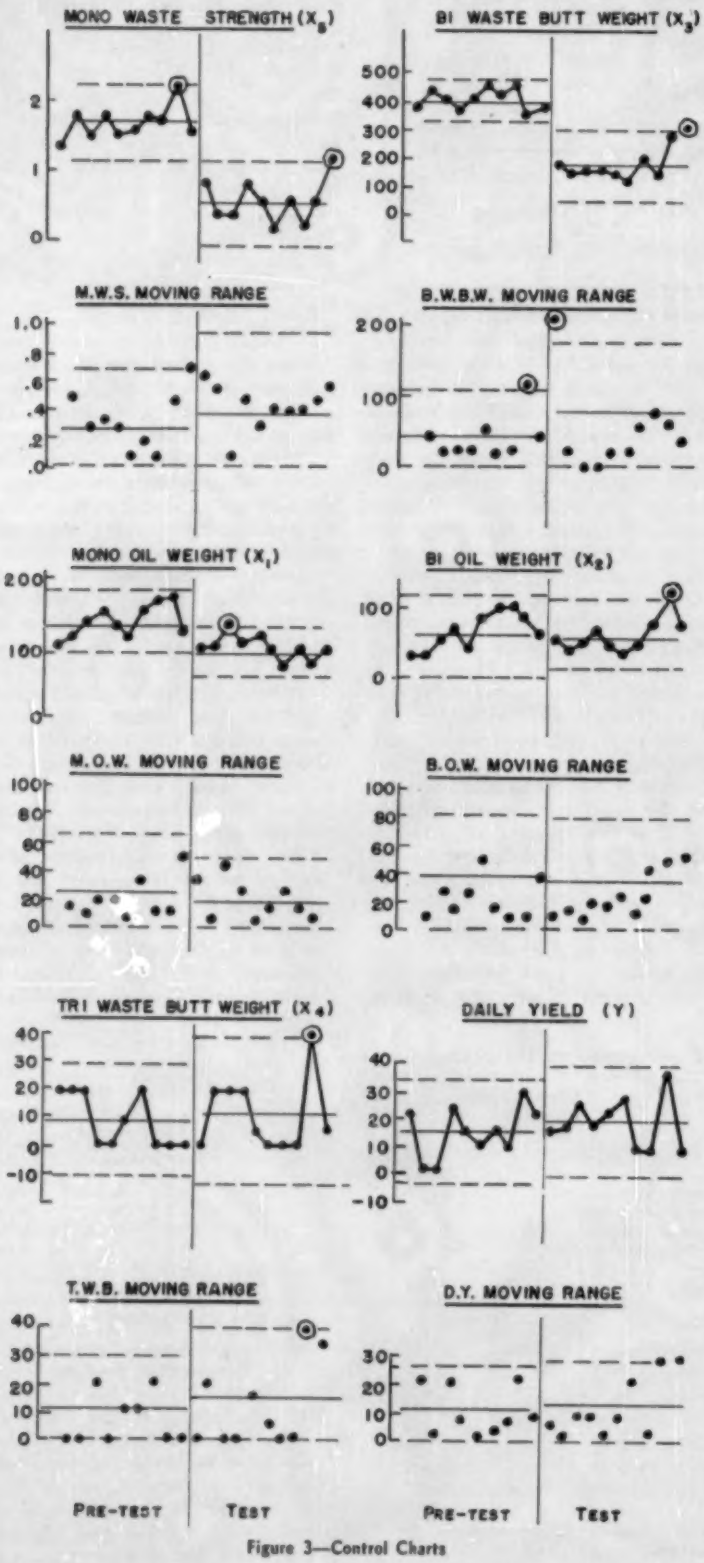

Figure 3—Control Charts

Prior to data evaluation a review of reaction chemistry was made to establish tentative hypotheses of interest that might be tested. It was postulated that even though an acid reduction at the mono stage might reduce the degree of reaction as evidenced by a decrease in mono oil weight, the bi stage might be adequately acid-rich to complete both reactions thus making the bi oil weight constant. In some cases, agreement could not be reached as to which were the controlling variables. To resolve the problem, a multiple regression was calculated to determine the influence of mono oil weight (x_1), bi oil weight (x_2), weight of bi waste butt (x_3), and weight of tri waste butt (x_4) on yield (y). Within the mono stage, the regression of mono waste strength (x_5) on bi waste butt weight (x_3) was of primary importance. Likewise, the degree of dependence of mono oil weight (x_1) on bi waste butt weight (x_3), and bi oil weight (x_2) on mono oil weight (x_1) could be tested from the calculations made during the multiple regression analysis. Quantitative knowledge of these relations, should they prove to be significant, would lead to better process understanding. Hence, although secondary to the original problem, their examination was warranted. Since the chemistry might change in the mono stage after the acid reduction, correlations were tested in two parts—using data taken during the control period before the plant test, and data covering both the control and test periods.

From the control charts, shown in Fig. 3, and the multiple regression and correlations summarized in Table I, it was concluded that:

1. The data do not indicate that any significant change in yield occurred.
2. The weight of bi waste butt (x_3) had been reduced and was controlled at the desired level, with the exception of the last two days, during which the production department had returned to the original level.
3. The mono waste acid strength (x_5) was materially reduced and controlled at a lower level. A least squares equation was derived for predicting mono waste strength from weight of bi waste butt (x_3) that agreed reasonably well with theory.

TABLE II—Effect of Correlation on Final Equation

Equation Containing	Partial Regression Coefficient for x_3	Percent of Total Variation Accounted for by Equation
y, x_1, x_2, x_3, x_4	$b_{3.124} = -0.244$	72.8
y, x_1, x_2, x_3	$b_{3.12} = -0.256$	70.5
y, x_2, x_3	$b_{3.2} = -0.214$	65.6
y, x_3	$b_3 = -0.178$	47.1

4. Mono oil weight (x_1) and bi oil weight (x_2) were significantly related during the pre-test period; however, the relation was not significant for the data covering both the pre-test and test periods. The significant drop in mono oil weight related to the reduction in bi waste butt apparently did not interfere with the bi nitration and overall yield.
5. Under conditions found in the pre-test period, yield (y) was significantly correlated with the weight of bi waste butt (x_3). Both mono oil weight (x_1) and bi oil weight (x_2) failed to correlate statistically with yield. However, they were kept in the regression equation calculated for prediction purposes, because they made sizable changes in the partial regression coefficients when omitted. This may be seen readily in Table II.

Furthermore, it was apparent that sufficient information had been developed from the data analysis to guide another plant test. From the relations identified, adequate predictions could be made to detect quickly whether any future test would perform according to schedule. Control charts for data evaluation sold themselves both as experimental and process control tools.

In retrospect, control charts contribute to batch process control and plant experimentation by:

1. Graphically portraying ranges within which variation is to be expected, and hence providing limits for action, thus eliminating misunderstanding about what constitutes significant modifications[16].
2. Focusing attention on natural process variation present in the process prior to change.
3. Questioning whether data collected are suitable for control. (In the above example, calculations based on cumulative yields were discarded since the variance of daily reported yields decreases from the first of the month to the last. On this basis, the date of a plant test would partially determine its outcome.)

In the part[illegible] example described above, control charts were not used for "within-batch" process control since no sufficiently rapid chemical analysis was available. Instead, "batch-to-batch" control was used to guarantee product quality.

Summary

Each type of batch control has a part to play in modern multi-stage control. Prior to selection, a balance must be made between cost of information gained and its control value[5]. More often than not the variables to be controlled for optimum regulation are not apparent. Multiple regression techniques[6a] and experimental designs[6] may be necessary to identify controlling factors. After identification, control charts may be used for daily checks on operating levels and as operator guides. In simplest form, control charts have justified their use if they awaken chemists and engineers to the natural variation of processes and lead to better control.

Acknowledgment

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TABLE III—Multiple Regression Solution—Pre-test Data

Corrected Sums of Squares and Cross Products

$Syx_1 = 645.246$	$Sx_1^2 = 4834.1$	$Sx_1x_2 = 4582.6$	$Sx_2x_3 = 2846.4$
$yx_2 = 479.596$	$x_2^2 = 7113.6$	$x_1x_3 = -803.1$	$x_2x_4 = -812.0$
$yx_3 = -2169.376$	$x_3^2 = 12194.1$	$x_1x_4 = -1047.0$	$x_3x_4 = 1027.0$
$yx_4 = -422.120$	$x_4^2 = 890.0$	$Sy^2 = 818.7404$	

Original Matrix

b_1	b_2	b_3	b_4	c
4834.1	4582.6	—803.1	— 1047	645.246
	7113.6	2846.4	— 812	479.596
		12194.1	1027	— 2169.376
			890	— 422.120

Auxiliary Matrix

4834.1	0.947974	—0.166132	—0.216586	0.133437
4582.6	2769.42	1.30288	0.0651953	—0.0476309
— 803.1	3607.72	7360.27	0.083944	—0.256835
— 1047.0	380.528	617.853	736.767	—0.156259

Final Matrix

$b_1 = -0.2064$
$b_2 = 0.2801$
$b_3 = -0.2437$
$b_4 = -0.1563$

$B_1 = -0.502$ (3)
$B_2 = 0.826$ (2)
$B_3 = -0.940$ (1)
$B_4 = -0.169$ (4)

Variance Analysis

Source	D. F.	S. S.	M. S.	F
Explained by b_3.	1	385.94	385.94	8.66*
Explained by adding b_1, b_2, and b_4.	3	209.87#	69.96	1.57
Residual	5	222.93	44.59	
Total	9	818.74		

Even if the entire S. S. were assignable to one variable alone, it would not be significant.
* Exceeds $F_{1,5;0.05}$. (x_3 alone accounts for 47 percent of the total variation).

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Practical Aids

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A Scatter Diagram Used to Compare "Before" and "After" Measurements

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Introduction

Scattergrams can often be used by engineers to study the relationship between two variables. They are useful because they frequently show very surprising but important relationships. Often certain relationships which are predicted by scientific knowledge will be found to hold for the majority of points, but there are usually a few mavericks or entire groups of points which behave unexpectedly. These peculiarities very often lead an inquiring engineer to effect fundamental improvements in his process.

During the early development stages of an electronic tube, too much variation of a certain electrical characteristic was being experienced at final test. This electrical characteristic depended (primarily) upon the internal relationships ("geometry") of the tube components. Unfortunately, however, this electrical characteristic cannot be measured until the tube has been completely sealed into its glass envelope; consequently there is no easy way to study the effects of manufacturing stages upon this electrical characteristic. However, it is possible to measure variations in the geometry of tubes indirectly by means of an auxiliary electrical characteristic (capacitance); and capacitance can be measured at several stages during the assembly of the tube to study possible effects upon the geometry.

This use of scattergrams to study qualitatively the relationship of a variable *before* a manufacturing stage to the same variable *after* the stage is a very general and useful approach to many problems in engineering and science.

Various patterns in engineering data can provide clues to the underlying behavior of a process and lead to engineering improvements, often by a technique no more complicated than the preparation of a scattergram.

The Problem

Changes in the internal geometry of a tube during manufacture can be estimated indirectly by observing changes in the capacitance of the tube. Most electrical characteristics of a radio tube cannot be measured until the tube has been completely assembled and processed but an exception to this rule is *capacitance*. This capacitance characteristic can be measured when the tube is still a "mount", (see Fig. 1), i.e., before the mount has been sealed into the bulb, and at several subsequent stages. It was decided for this study to make capacitance readings at intermediate stages of manufacturing as a means of studying the effect of successive manufacturing operations upon the internal tube geometry, hoping to find the major stage in manufacturing which was contributing to the excessive geometric variability. These changes are difficult to associate with successive manufacturing stages in any other known way, unless they are quite extreme.

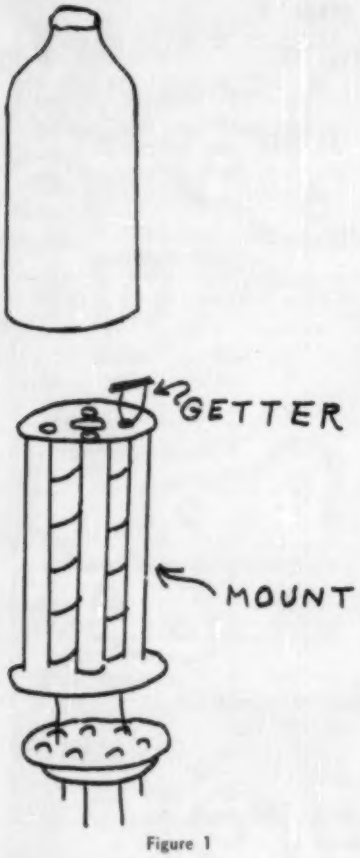

Figure 1

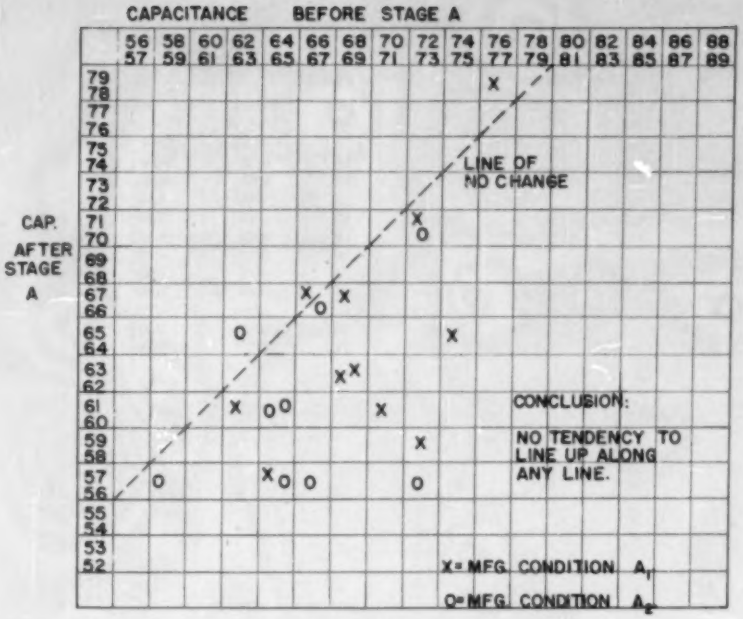
CAPACITANCE BEFORE STAGE A
CAP. AFTER STAGE A
LINE OF NO CHANGE
CONCLUSION:
NO TENDENCY TO LINE UP ALONG ANY LINE.
X= MFG. CONDITION A1
O= MFG. CONDITION A2

Figure 2—Experiment No. 1

Planning the Procedure

In a discussion with a planning group of technical men who were associated with the problem (a development engineer, a production foreman, and a quality control engineer) it was decided to study the effect of each of two manufacturing stages*, Stage A and Stage B, upon capacitance.

Columns 1 and 2 (Table I) are readings made *before* and *after* Stage A. Columns 2 and 3 are readings made *before* and *after* Stage B.

After the readings in Column 1 had been made (in random order), all mount assemblies were inserted in bulbs. Half of them (12) were then sent through Stage A at a temperature of 900°, (Mfg. Condition A_1), and half at 800°, (Mfg. Condition A_2), as agreed by the planning group. Capacitance readings after Stage A were measured and recorded as shown in Column 2 of Table I (Identifying numbers had been marked on individual tubes in the two groups.)

Experiment No. 1

Figure 2 represents a scatter diagram presenting a visual relationship between Columns 1 and 2:

Horizontal axis: represents the capacitance *before* Stage A.

Vertical axis: represents the capacitance *after* Stage A.

On Tube No. 1, for example, the readings (in appropriate units) before and after Stage A were 0.73 and 0.70 respectively. In making the scatterdiagram, we located the row* labelled 0.72—0.73 and the column labelled 0.70—0.71. Then in the square which is common to this row and this column, a cross (x) has been entered. (An x indicates Manufacturing Condition A_1, i.e., 900 degrees). Similarly, x's were marked corresponding to pairs of values (before and after) of the remaining tubes sealed at 900 degrees. Similarly, circles (o) were marked for the twelve pairs of readings from tubes processed under Manufacturing Conditions A_2 (800 degrees). (*Note:* Different colored pencils pro-

*Technical information for the tube engineer only.
Mfg. Stage A: (the effect of temperature during exhaust, bulbing and sealing)
Mfg. Stage B: (the effect of flashing the "getter")

*Thus the data have been "grouped" in the same way that we group data to make a frequency histogram. A cell-width is chosen (arbitrarily) so as to give (preferably) as many as 13 cells and not more than 20. It is not necessary to choose the same cell intervals on the horizontal and vertical axes.

TABLE I

At 900 degrees				At 800 degrees			
Tube No.	(1) Before Stage A	(2) After Stage A but before Stage B	(3) After Stage B	Tube No.	(1) Before Stage A	(2) After Stage A but before Stage B	(3) After Stage B
1.	0.73	0.70	0.70	13.	0.64	0.60	0.61
2.	0.62	0.60	0.64	14.	0.73	0.57	0.60
3.	0.68	0.53	0.55	15.	0.64	0.57	0.59
4.	0.65	0.56	0.58	16.	0.58	0.56	0.56
5.	0.66	0.66	0.71	17.	0.66	0.66	0.68
6.	0.69	0.66	0.66	18.	0.67	0.57	(Broken)
7.	0.72	0.58	0.60	19.	0.72	0.70	(Broken)
8.	0.69	0.63	0.69	20.	0.73	0.62	0.65
9.	0.68	0.62	0.64	21.	0.64	0.60	0.60
10.	0.75	0.65	0.72	22.	0.66	0.60	0.62
11.	0.76	0.78	0.79	23.	0.63	0.65	0.64
12.	0.70	0.60	0.62	24.	0.77	0.60	0.63

TABLE II

At 900 degrees				At 800 degrees			
Tube No.	R-1 Before Stage A	R-2 After Stage A and before Stage B	R-3 After Stage B	Tube No.	R-1 Before Stage A	R-2 After Stage A and before Stage B	R-3 After Stage B
1.	0.66	0.60	0.62	13.	0.75	0.68	0.71
2.	0.72	0.57	0.63	14.	0.56	0.49	0.54
3.	0.68	0.55	0.57	15.	0.72	0.59	0.63
4.	0.70	0.60	0.64	16.	0.66	0.56	0.62
5.	0.64	0.64	0.70	17.	0.62	0.52	0.55
6.	0.70	0.58	0.62	18.	0.56	—	—
7.	0.72	0.56	0.59	19.	0.65	—	—
8.	0.73	0.62	0.66	20.	0.88	0.87	0.88
9.	0.82	0.62	0.67	21.	0.56	0.46	0.50
10.	0.66	0.60	0.66	22.	0.76	0.77	0.79
11.	0.72	0.62	0.65	23.	0.72	0.69	0.76
12.	0.84	0.87	0.88	24.	0.74	0.70	0.70

vide an easy way to distinguish different groups on a scatterdiagram).

Now, if *no change* were to occur in capacitance during Manufacturing Stage A, the marks (whether crosses or circles) would lie along a straight line; furthermore, they would line up along the dotted diagonal line which *indicates no change* between the "before and after" readings during Stage A.

Engineering Analysis: There is essentially no *tendency* to form a line either along the dotted line or any other line—this is true whether we consider the crosses or the circles in Fig. 2. We conclude, then, that Manufacturing Stage A is *deforming* the geometry in such a way that we cannot predict its effect upon the geometry of an individual tube under either Condition A_1 or A_2. However, we cannot decide from these data which phase of Stage A is introducing the deformation since there are three of them (mounting, sealing-in, and exhaust) between the *before* and *after* readings.

Experiment No. 2

Following Experiment No. 1, the planning group discussed the next step. It was agreed finally to introduce a certain change in Manufacturing Stage A, and then make another study at Stage A. The data of the second study are shown in Table II and the scatterdiagram in Fig. 3.

Engineering Analysis: (Stage A) (See Fig. 3)

At 900 degrees: There is no tendency for the crosses (x) to line up.

At 800 degrees: There is a definite tendency for the circles (o) to line up although not along the diagonal dotted line.

There is a difference in the patterns corresponding to the twelve tubes sealed-in at 900 degrees and the twelve tubes sealed-in at 800 degrees (and which have had the same manufacturing treatment in other respects). The 900 degrees temperature is deforming the internal geometry in an unpredictable manner, but the scatterdiagram corresponding to the 800 degrees temperature shows a definite tendency to line-up.

Thus, there is evidence that the 900 degrees condition at Stage A is deforming the internal geometry in an unpredictable and undesirable manner, but an indication that this can be prevented by using a lower exhaust temperature of 800 degrees.

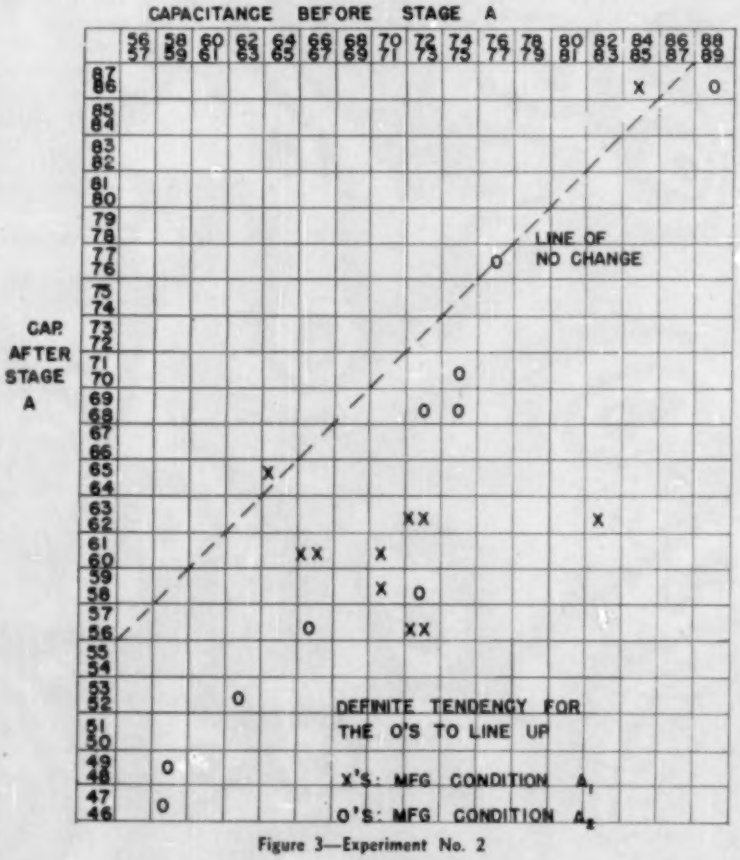
CAPACITANCE BEFORE STAGE A
CAP. AFTER STAGE A
LINE OF NO CHANGE
DEFINITE TENDENCY FOR THE O'S TO LINE UP
X'S: MFG CONDITION A1
O'S: MFG CONDITION A2

Figure 3—Experiment No. 2

Note: In both Fig. 2 and Fig. 3, most of the points are *below* the diagonal dotted line (of equality). From the way the scatter diagram has been set up, this means that the readings after Stage A are lower than the readings before Stage A. Consequently, the processing of Stage A has a tendency to lower the average capacitance in a fairly uniform fashion. (A shift in a test instrument could produce the same effect.)

Experiment No. 3

A scatterdiagram showing the relationship between capacitance before Stage B (i.e., after Stage A) and *after* Stage B is shown in Fig. 4; data from both Table I and Table II have been used to prepare Fig. 4. The line-up is very good; in fact, if one were to compute the correlation coefficient, r, by the standard procedure, its value would be found to be approximately $r = 0.85$. There seems to be no reason to perform the computation here.

Engineering Analysis: (Stage B). Stage B has a very negligible effect upon the capacitance; there is only a slight increase during Stage B.

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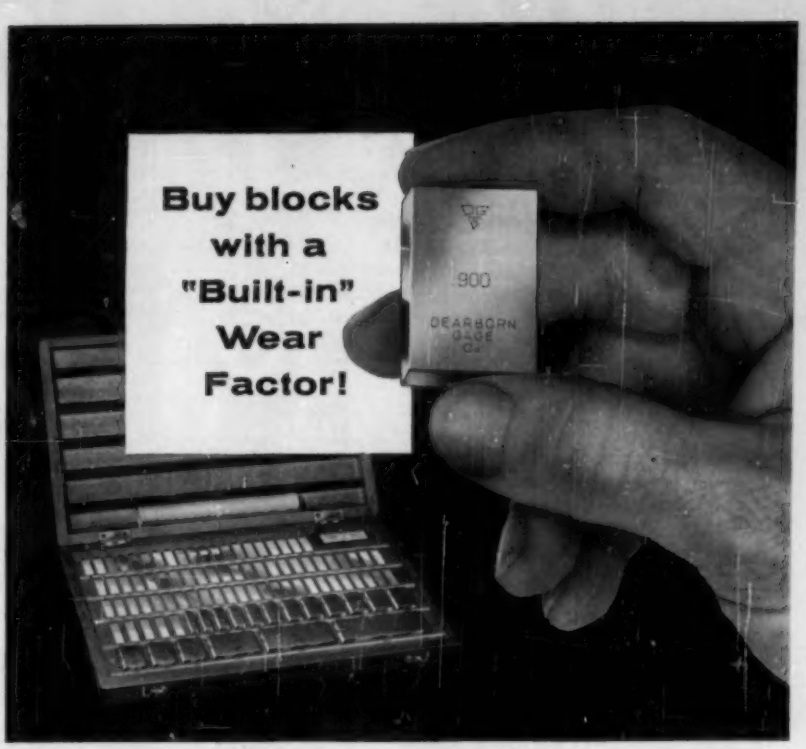

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Summary

Olmstead[1] has indicated certain patterns of data involving one independent variable which indicate assignable causes of interest to an engineer. He indicates certain tests which are useful in detecting these types of assignable causes. When we study possible relationships of one variable to another, we then become interested in the pattern of points with respect (ordinarily) to a diagonal line. The data may include variations of the types listed by Olmstead: gross errors or mavericks; trends; abrupt shifts; short, fast cycles; and long cycles. The tests suggested for the existence of these patterns with respect to a horizontal line can often be extended or adjusted to diagonal lines. It is desirable that an article be written to explain any necessary adjustments. But in the meantime a simple scattergram gives valuable clues which are often entirely adequate for engineering improvements. They often provide more information of value than the more traditional computation of the correlation coefficient r. The computation of r from data containing assignable causes usually gives too low a measure of the underlying relationship between the two variables. It is recommended that any computation of r be postponed until the scattergram has been studied.

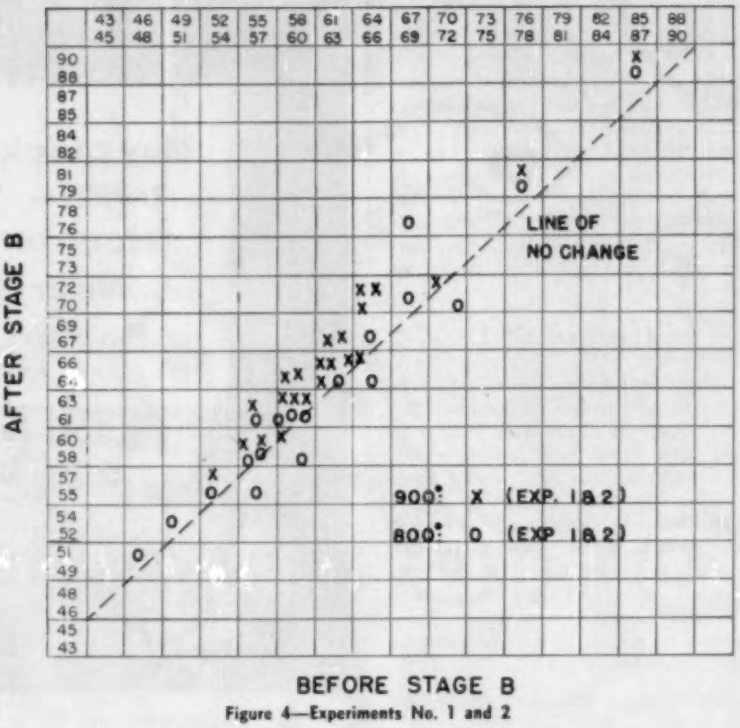

Figure 4—Experiments No. 1 and 2

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(2) Terry, Milton E., "On the Analysis of Planned Experiments," 1955 ASQC Convention Transactions, p. 553-556.

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Local Section News

" . . . BUT NOT FORGOTTEN"

ALBUQUERQUE The April meeting was held at Mitchell Hall, University of New Mexico. The guest speaker was W. R. Davison, Rocket Fuels Div., Phillips Petroleum Co., McGregor, Texas. Mr. Davison's topic was "Some problems related to the selection of AQL."

ALLENTOWN-BETHLEHEM The April meeting was held jointly with the local section of the American Society of Tool Engineers at the Hotel Traylor in Allentown, Pa. This combined meeting was a follow-up of last year's session and the tool engineers expressed their desire for more information on how statistical quality control can help them. The feature talk was by the well-known consultant for Western Electric Co., Miss Bonnie B. Small, on a "Talk to engineers about quality control." A question and answer period followed.

BOSTON A joint meeting with the Boston section of the American Statistical Association was held on Apr. 10. A. C. Rosander of the Internal Revenue Department discussed the application of QC techniques to income tax operations.

BUZZARDS BAY Axel U. Sternlof, American Steel & Wire Co., Worcester, was the main speaker at the Apr. 9 meeting. His subject was "Quality control in the wire industry." Illustrating his lecture with slides, he demonstrated how the use of statistical

techniques in the manufacture of diversified products will enable New England industry to compete with the best industrial craftsmen of the West and Midwest.

Announcement was made that 13 people have enrolled in the basic quality control course sponsored by the section. Joseph G. Kowalski of the Firestone Industrial Products Co. in Fall River is instructor for the seven session course.

CHARLESTON The April meeting featured an address on "Practical control of quality in the coal industry" by Les Sutherland, research consultant for Truax-Traer Coal Co.

On Apr. 17, Leon Bass, Vice President of ASQC, presented the charter of the section to chairman R. M. Berg and the executive committee at a special meeting held at the Charleston Press Club. The above photo shows Mr. Bass (left), Mr. Berg, and the much coveted charter.

CHICAGO A joint meeting of the section and the Electronics Division was held at Chicago's Navy Pier on Mar. 27. The principals of the panel discussing the subject "What does management expect from quality control" are shown above. They are, from left to right, Donald MacGregor, Zenith Radio Corp.; Bernard G. Sahlins, The Pentron Corp.; William L. Lieberman, The Pentron Corp.; Frederick K. Stamm, Lenz Electric Mfg. Co.; and Joseph T. Heller, Dearborn Electronics Laboratories.

On Apr. 10, Dr. Harry E. Sagen of Abbott Laboratories, Inc., delivered a talk on "Developing a quality attitude." One of the most important lessons learned from this interesting program was that a quality attitude of members of the production team requires thorough understanding of the need for attaining a specific quality goal.

COLUMBUS Our annual social evening with a dinner for the ladies was held Apr. 27 at the Colony Restaurant. Mrs. Gloria Strong, Ohio Bell Telephone Co., gave a very interesting and informative talk on "The men on my line."

CORNING -ELMIRA Over 50 members and guests were honored to hear R. M. Hofstead of Bristol Laboratories, Syracuse, N. Y. speak on "SQC in manufacturing" on Apr. 9 at the Langwell Hotel, Elmira. Prior to the meeting, a plant tour of the General Electric plant in Elmira was enjoyed. The section's thanks go to our treasurer, Willis Williamson, for arranging such an interesting tour.

DELAWARE Thirty-three members and guests attended the Apr. 4 meeting. This included an afternoon tour of the International Latex Corp. plant at Dover, Del. and a panel discussion in the evening conducted by members of the International Latex quality control team.

DENVER The April meeting was highlighted by a tour of the Sundstrand Aviation-Denver plant. Morris Hickey, director of quality control, together with members of his staff, acted as guide for the tour. Uses of QC in various phases of the factory were explained. Coffee and rolls served in the Sundstrand cafeteria concluded the tour and permitted members to discuss the tour and many new ideas for use in their companies.

GEORGIA The Atlanta group met on Apr. 30 and heard a talk on "Some comments on application of statistical methods in accounting" by Dr. John H. MacKay, Georgia Institute of Technology. Visitors included representatives from the National Association of Cost Accountants, Georgia Society of Certified Public Accountants, Atlanta Society of Controllers, and the American Society of Women Accountants.

A questionnaire has been distributed to the members to learn their preference for local meetings and programs. The returns will be used to plan the fall program.

GRAND RAPIDS An attendance of 50 members and guests was attracted to the Apr. 25 dinner meeting to hear an unusually interesting talk presented by Mr. Kanter, staff representative of the UAW-CIO. Mr. Kanter's duties with the UAW-CIO include time study, job evaluation, and work standards; hence the topic "The union looks at quality control" was interesting, factual, and well received.

GREATER MUSKEGON Thirty-five members attended the dinner meeting held Apr. 11 to hear J. B. Cobb of the research department of Standard Oil Company of Indiana. His topic was "Quality control in a petroleum refinery." The presentation was very interesting and informative which was proven by the activity of the informal discussion which followed the talk.

HARRISBURG On Apr. 6 about 65 members and guests enjoyed our annual panel discussion at Warner's Dairyland in Red Lion. The interest and participation was the best yet at one of these programs. In fact, one of the subjects scheduled for discussion had to be omitted because of the late hour.

KANSAS CITY Roy A. Wylie, Micro Switch Div., Minneapolis-Honeywell Corporation, Freeport, Ill. was the guest speaker at the April dinner meeting which was held at the Blue Hills Restaurant. Mr. Wylie's subject "Analysis of Variance" presented the statistical techniques that provide the classification of variation in a process or product into meaningful components.

LOS ANGELES The Apr. 16 meeting continued the series of discussions on reliability. At the clinic session, Dr. O. B. Moan discussed the mathematical principles in reliability particularly for elements in series, in parallel, or in any combination of series or parallel arrangements. The results of his researches have appeared in the February and April issues of *Control Engineering*, and his final installment will appear in the June issue.

MEMPHIS The April meeting was held at the Continental Baking Co. T. Y. Hicks of the Service Bureau Corp. was the speaker. He described some of the uses of computers in industry, particularly in the field of quality control, and explained the services available to industry and business through the Service Bureau Corp., a subsidiary of IBM Corp.

MEXICO CITY On Apr. 25, a dinner meeting was held at which time certificates were presented to those who completed the spring course on statistical quality control which was conducted from March 4 to April 8. This was the twelfth course offered by the section.

MICHIGAN On Apr. 19, all committee chairmen met at the home of the newly elected chairman Harmon S. Bayer. Plans for the 1957-58 year were formulated. Plans were started on a section family picnic with a tentative date of Aug. 24.

MUNCIE This section held its regular monthly meeting on Apr. 11 in the Pine Shelf Room of the L. A. Pittenger Student Center. G. W. Howard of Convair's Ft. Worth Division was the speaker. The bread and butter title of his remarks was "A SQC program which speaks management language—dollars."

NEW HAVEN A clinic meeting was held at the Hamden Plains Methodist Church on Apr. 23. The topics for discussion were "Design of experiments" and "Problems in quality control management.

RACINE Program chairman Earl Godard did a terrific job in inviting Prof. Gayle W. McElrath, University of Minnesota, as speaker of the evening on Apr. 8. Prof. McElrath spoke on "Some quick and easy statistical methods" and held the section spellbound until the end of his address.

ST. LOUIS At the Apr. 26 meeting Norman R. Moss, IBM Corp., gave a very informative talk on "Computers as applied to statistical calculations."

SALT LAKE CITY The largest crowd of the season turned out to hear Richard Ede of the U. S. Steel Co. present "Special statistical methods as applied to the metals industries." The sharpness of the simply-presented advanced techniques in uncovering trouble areas where apparently none existed, caused the question and answer session which followed, to go far beyond the usual closing time.

On Apr. 25 Don Loomer, Salt Lake Refining Co., played host to a large crowd of members and guests by asking them on a three hour conducted tour of the laboratory and the control room of the catalytic cracking plant. The flow of quality control samples from plant to laboratory was demonstrated along with the dissemination of information from the laboratory back to the plant.

SEATTLE On Apr. 9 this section visited the Kaiser Aluminum Company's reduction plant in Tacoma. Following a brief orientation, the group toured the plant and the testing facilities.

SOUTH TEXAS H. J. Jacobson of the P. R. Mallory Co. was the principal speaker at the April meeting. The following slate of candidates for the new year was presented to the section by the nominating committee: Chairman J. G. McQuarrie, vice chairman Ken Keneaster, secretary R. Shappee, and treasurer A. R. Stark.

TORONTO The annual general meeting of the Toronto section was at the "Sign of the Steer" Restaurant on Apr. 10. Reports on the year's progress were made to the members. Speaker of the evening was Miss Bonnie B. Small, Western Electric Co., whose subject was "Control chart analysis for engineering experiments."

On Apr. 24 the section visited the Malton Plant of Orenda Engines, Ltd. In addition to being shown the production facilities for the manufacture of jet engines, members heard their host, L. E. Marchant, chief inspector and quality control manager, talk on the principles of operation of gas turbines and the quality control problems related thereto.

Toronto All-Day Forum

One of the largest single day conferences in the history of ASQC was held in Toronto, Ont. on Mar. 9. Organized by the Toronto section and held on the campus of the University of Toronto, it was attended by 440 members and guests.

Most popular was the all day general training course, conducted by W. A. MacCreahan, Radio Div., Bendix Aviation Corp.

Speaking on specialized subjects were C. R. Burdick, F. Norris, L. M. Freeman, Simon Collier, Dr. A. V. Feigenbaum, L. E. Marchant, M. T. Neill, L. F. Myers, C. A. Bicking, and M. V. Morreale.

Responsible for the success of the forum were the members of the Forum Committee: M. A. Smith, chairman; W. F. Foskett, program; J. D. Butler, secretary; J. E. Boradman, treasurer; R. T. de la Rosa, arrangement; and F. G. Thompson, publicity.

The climax of the day's activities was the banquet at which the address was given by H. D. De Young, President, Atlas Steel Corp.

WINDSOR Ralph E. Burt, President of the National YOU Association, Springfield, Mass., used "Quality communications and employee relations" as the theme of his talk at the April meeting. He outlined methods of improving employee relations through better leadership and improved communications between the supervisors and the workers with regard to quality.

His talk proved to be of mutual interest to the workers and members of management who were present as special guests.

WINNEBAGO About 50 members and guests enjoyed the instructive address on "Statistical techniques in industrial engineering problems" given by Dr. Marvin Mundel at the Apr. 8 meeting. The Marquette University professor related several excellent examples, with the aid of slides, showing problems and methods of solution. He aptly made clear that statistical quality control and its proper application are of great necessity in the sound industrial engineering complex.

The training session was attended by 40 members. Dr. Carl Noble, Kimberly-Clark, discussed "Significance tests."

" . . . CAST THEIR SHADOWS BEFORE"

DELAWARE Regular monthly meetings are not held during the summer months but the officers and directors and other members of the executive committee will continue to meet throughout the summer to complete plans for the 1957-58 season.

DENVER The final business meeting of the year will be held during June. The committee selected for nomination of officers will report at that time and officers for 1957-58 will be elected.

"AS YE SOW . . ."

BOSTON The 4th annual seminar "Quality control for management" will be held during the third week of June. The same nationally-known faculty that presented the previous sessions will conduct the seminar meetings under the able direction of Len Seder.

TAPPI COURSE JULY 8-19 The sixth annual TAPPI course on the use of statistical methods in the paper industry will be held on the campus of the University of Washington, Seattle, from July 8 to July 19.

As in recent years, the course will consist of a basic course and an advanced seminar, running concurrently.

The basic course will deal with paper-mill applications of the basic statistical techniques. It is intended for those who wish to acquire some knowledge of, and facility with, these simpler but exceedingly valuable statistical techniques and those who have had little or no previous formal training in statistical methods.

The advanced seminar is intended for people who have experience and definite facility in the use of the simpler techniques and who wish to gain training and practice in the special problems that arise in applications.

Enrollment is limited to 40 in the elementary course and to ten in the advanced seminar.

The teaching staff will include: Geoffrey Beall, Gillette Safety Razor Co., Boston, Mass.; K. E. Vroom, Pulp & Paper Institute of Canada, Montreal, Canada; and J. B. Brown, Crown-Zellerbach Corp., Camas, Wash.

Fee for the course, including the cost of instruction, textbooks, course material, board and lodging, will be $200 for the elementary course and $300 for the advanced seminar.

Applications for enrollment should be sent to: Dr. Joseph L. Mcarthy, Department of Chemical Engineering, University of Washington, Seattle 5, Wash.

Requests for further information should be sent to Fred R. Sheldon, Becco Chemical Div., Food Machinery and Chemical Corp., Station B, Buffalo 7, N. Y.

NEW DEVELOPMENTS IN INSTRUMENTAL ANALYSIS A special summer program "New developments in instrumental analysis" will be offered at the Massachusetts Institute of Technology Aug. 26-30.

The level of the lectures will be such as to make them useful to the chemist who has had some experience with the common instrumental methods. Among the topics to be discussed will be; derivative and differential techniques, oscillographic and alternating-current polarography, current-voltage-time methods such as chronopotentiometry, gas chromatography, scintillation counting, spectrofluorimetry, photometric titrations, and thermometric titrations. The basic principles and theory will be given for each method as well as typical applications in research and analysis.

Tuition for the one-week program will be $150.

Further information regarding this course can be obtained by writing to Office of the Summer Session, Room 7-103, Massachusetts Institute of Technology, Cambridge 39, Mass.

"FOR MANY ARE CALLED, BUT FEW ARE . . . "

ALBUQUERQUE Newly elected officers of the section are: chairman—John M. Wiesen, Sandia Corp.; vice chairman—Allen L. Thornton, Sandia Corp.; secretary—John C. Gaskins, Amer-

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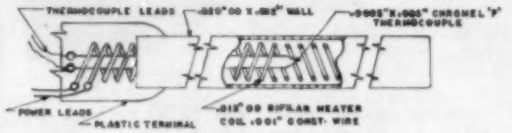

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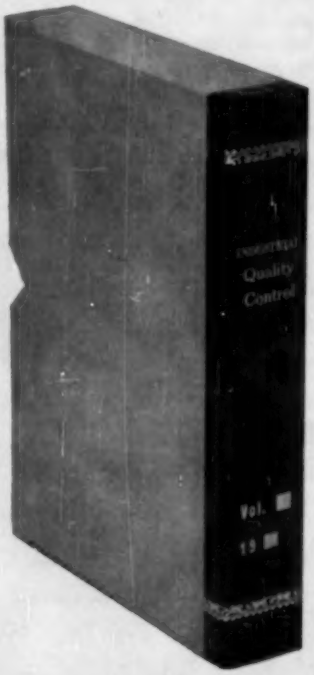

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ican Car and Foundry Corp.; and treasurer—George O. Hawley, Sanida Corp.

BOSTON At the annual meeting in April, the following section officers were elected: chairman—Harry Duane; vice chairman—Miss Dorothea Looney; treasurer—Martin Rogers; secretary—William Donovan.

CHARLESTON The officers elected to lead the section during the next year are: chairman—C. M. Drummond, du Pont; vice chairman—E. O. Lail, C & P Telephone Co.; treasurer—H. C. Morton, Carbon Fuel; and secretary—C. J. Kennett, Carbide.

COLUMBUS Officers for the ensuing year: chairman—Roy Cowin, Kimble Glass Co.; vice chairman—Ed Haigh, Timken Roller Bearing Co.; secretary—Ray Miller, Jeffrey Mfg. Co.; and treasurer—Don Seelbach, Denison Engineering Co.

CORNING -ELMIRA The results of the election for officers of the section have been announced. The officers for the coming year are: chairman—Herman Albertine, Westinghouse Electric Corp.; vice chairman—E. B. Godsey, Corning Glass Works; secretary—Willis Williamson, General Electric Corp.; treasurer—Alan Stone, Corning Glass Works.

GREATER MUSKEGON Officers for the 1957-58 year were elected as follows: chairman—M. V. Pascavis, Muskegon Piston Ring Co.; vice chairman—Merril Bailey, Anaconda Wire & Cable Co.; secretary—Ray Porter, Muskegon Piston Ring Co.; treasurer—Basil B. Smith, Michigan Spring Co.

HARRISBURG The officers elected at our April meeting for the 1957-58 year are as follows: chairman—C. W. Brosey, AMP, Inc.; vice chairman—S. A. Combs, Borg-Warner Corp.; secretary—I. J. Bearer, Schick, Inc.; treasurer—D. J. Goodall, Thompson Products.

MEMPHIS The officers for the 1957-58 season were announced as follows: E. D. Robinson, chairman; H. D. Green, vice chairman; F. B. McDaniel, treasurer; and M. L. Brandon, secretary.

NEW HAVEN Preceding the April meeting, an election of officers was held for the 1957-58 season. The elected officers are: chairman—Dave Albert, Avco Lycoming Division; vice chairman—Dan Grove, Revere Corp. of America; secretary—George Georgis, Revere Corp. of America; treasurer—William Ajello, Westport Development and Mfg. Co.

TORONTO At the annual general meeting of the section the following were elected as the 1957-58 executive: chairman—M. J. O'Callaghan, British American Oil Co., Ltd.; vice chairman—M. F. Ward, Avco Aircraft, Ltd.; secretary—H. W. Kempling, Collings Radio Co. of Canada, Ltd.; treasurer—J. D. Butler, International Business Machines Co., Ltd.

NEW JERSEY PHARMACEUTICAL QC GROUP The Pharmaceutical Quality Control Group of New Jersey has elected the following members to serve for the year ending March, 1958: chairman—William M. Spencer, Jr., Bristol-Myers Co.; secretary-treasurer and chairman

elect—Joseph W. Kouten, Carroll Dunham Smith Pharmacal Co.; secretary and treasurer elect—Robert A. Miller, E. Bilhuber, Inc.

DIVISIONS

Administrative Applications Division

The Division's first technical conference was held at the Congress Hotel in Chicago on Feb. 8-9 with 209 registrations for the entire conference. In addition 149 registered for various parts. The program was very diversified with 18 speakers plus A. F. Jacobson's talk at Friday's luncheon.

The nominating committee has selected the following candidates for division officers for the year 1957-58: chairman—Paul A. Robert, Gruen Watch Co.; vice chairman—Carl E. Noble, Kimberly-Clark Corp.; secretary—William F. Buhl, B. F. Goodrich Co.; treasurer—Samuel H. Troxel, Jr., Ohio Bell Telephone Co.

Chemical Division

A fourth session of the Chemical Division course on the Box method of experimentation was offered at MIT with Dr. J. S. Hunter of Princeton University Statistical Techniques Group instructing.

The Division has succeeded in gaining new members by sending a brochure on the advantages of membership plus the latest issue of "Chemical Division News" to all non-member participants in chemical industry conferences, training courses, etc. In the case of the symposium on the use of statistical methods in the chemical industry held recently at Stevens Institute of Technology, this meant a mailing of over 400 pieces.

SIGNIFICANT DIFFERENCES

Austin Fraser, formerly with A.M.F., has recently joined the QC staff of Raytheon Manufacturing Co., Missile Division, Andover, Mass.

Lee Fantz of the Calumet sub-group, Chicago section, now holds the position of vice president and director of manufacturing at the East Chicago, Indiana plant, Magnesium Company of America. He was formerly associated with the Anderson Co.

Wm. Wahrhaftig has taken over as instructor in a course on statistical quality control at Pasadena City College for the remainder of the spring term.

Emerging from the merging of the Broderick Company was this happy news: D. G. Browne, formerly sales manager of the company, was promoted to vice president, sales. "Brownie" is a Fellow of the Society and a member of the Muncie section as well as an executive director of the Society and an all around Society stalwart. Congratulations, Brownie!

Congratulations to Andrew Millar on his appointment to the position of staff assistant to the operating manager of Chrysler Corporation of Canada, Ltd. In his former position of assistant general superintendent of the motor plant, "Andy" did much to assist the Windsor section. We wish Andy every success in his new position.

Ervin E. Schiesel

It is with a profound sense of real loss that we report here the tragic death of Ervin E. Schiesel who was killed in an automobile accident on the Wilbur Cross Parkway in Connecticut about 1:30 pm on Tuesday, April 16, 1957. Details of the cause of the accident are still not clear, but his car crashed head-on into a bridge abutment and it is believed his death was almost instantaneous. There were no witnesses to the accident, and no evidence of skid marks indicating that Erv was aware of impending danger. He was 35 years old.

Erv graduated from Meriden High School and the Stevens Institute of Technology, and he held a master's degree from Columbia University. In World War II, he served as a lieutenant in the U. S. Navy on the aircraft carrier USS Enterprise, receiving a citation from James Forrestal, Secretary of the Navy, for his many contributions to engineering during the war.

He was president of the Arrowhead Associates in Meriden and vice-president of engineering and sales at the Mattatuck Manufacturing Company in Waterbury. The company which he headed was distinguished by the fact that it employed only handicapped persons in its factory. To quote from an editorial in the Hartford Journal, "Many of them, in the eyes of those less gifted in understanding than Mr. Schiesel, were hopelessly crippled. Some were double amputees. Others were blind. Nearly all had been on relief when this young executive gave them their opportunity. His whole staff of more than 25 persons became self-supporting, some to the extent that they were able to pay a substantial income tax. It was proof, all around, that the profit motive and humaneness can get along well together, if one wants them to."

Erv was a member of the Southern Connecticut Section of ASQC and had long been active in SQC work. He served as Regional Director for the New England Region in 1952-53, as an Executive Director in 1953-54 and 1954-55, as ASQC Treasurer in 1955-56, and was a Vice President of the Society at the time of his death. He was a member of the faculty of the University of Connecticut, serving as a guest lecturer on quality control.

In addition to his parents, Erv is survived by a sister, Mrs. Sidney Shindell, of New Haven. Funeral services were held Thursday, April 18 in the vestry of Temple B'nai Abraham in Meriden.

Not only the American Society for Quality Control, but the entire society of human fellowship has lost a warm and valued friend and leader through this fatal accident.

It is with deep regret that the Syracuse section reports the sudden and untimely passing of its treasurer, Mr. Gerald N. Gaynor, on Januay 19, 1957. Jerry was an ardent and enthusiastic officer and his inspiring personality will be greatly missed by those who worked with him.

The Kansas City section lost a faithful member recently in Clyde G. Atchinson. Mr. Atchinson, assistant chief metallurgist at the Sheffield Steel Corporation, was one of the early members of the section and served in many capacities in the growth of the section. He will be truly missed.

What's New?

ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL

The Sheffield Corp., Dayton 1, Ohio has developed a new Column Type Precisionaire air gage spindle for inspecting narrow width circular parts with large inside diameters. Prior to the development of the new spindle design, loading and unloading narrow parts with large size bores presented a problem in mass production inspection because the part frequently became cocked or hung on the spindle. The new gage consists of an angled spindle incorporating three sets of Plunjet gaging cartridges connected to a three column Precisionaire gage. To use, the operator presents the part to the spindle and glances at the position of the floats in the Precisionaire to read average diameter and the amount of out-of-roundness. In the illustration one of the new gages is being set up with a master setting ring for checking automobile flywheel ring gears.

★ ★ ★

Accurate pressure calibrations not ordinarily possible with oil dead-weight testers or mercury manometers can now be accomplished with a new primary pressure standard available from **Consolidated Electrodynamics Corp.**, 300 North Sierra Madre Villa, Pasadena, Calif. Operating as an air dead-weight tester, this instrument offers the advantages of a frictionless pressure medium, extreme accuracy even at pressures of less than one psi, and portability regardless of the pressure range. Pressure calibration is achieved by balancing controllable air pressure against the force generated by a weighted piston. When the piston is lifted and held in a suspended posi-

MEET OUR 10,000th MEMBER

While processing applications during April, the Headquarters Office found that Reinhold Fischer's application was the 10,000th application for membership in the Society. The fact that Mr. Fischer is a member of the Charleston section, one of the very recent additions to our family of sections, is significant in that it points up the way in which our Society is growing and is fast gaining recognition as an important and indispensable tool of industry.

The pictorial description of this event shows Robert Berg, (left) chairman of the Charleston section, welcoming Reinhold Fischer, on behalf of Society president Dale Lobsinger, as the 10,000th member to be processed into the Society.

Our heartiest congratulations to Mr. Fischer for achieving this distinction.

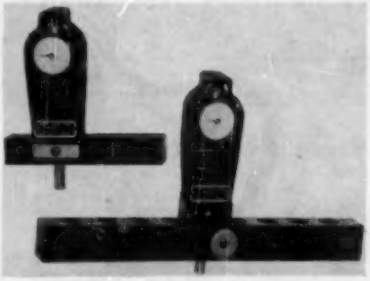
tion by air pressure, a given pressure has been established. This same pressure, fed simultaneously to the device under test, provides the means for calibration. The pressure medium—air—is practically frictionless. Friction between cylinder and piston is dispelled by momentarily actuating a motor-clutch assembly, which starts the piston rotating. The basic unit houses a drive motor and an assembly on which one of a selection of piston-cylinder combinations can be mounted. The upper part of the unit is fitted with a glass cover. When the Standard is used as a gage–type instrument, a dry air supply, a regulator, and the device being calibrated are all that is necessary. Under these conditions, the glass cover serves merely as protection against dust. However, when the unit is used as an absolute device, the cover provides a seal to the case and the unit can be evacuated through the reference-pressure fitting. This feature of the instrument allows it to be used directly for calibrating an "absolute" type transducer. Once the glass chamber has been evacuated, the weights are referenced to essentially absolute zero pressure rather than ambient pressure.

★ ★ ★

A new portable, self-powered vibration testing instrument which will enable companies to set up routine programs of seeking out vibration and establishing acceptable tolerances in production, inspection and maintenance, has been announced by **International Research & Development Corp.**, 797 Thomas Lane, Columbus, Ohio. The Model 305 Portable Vibration Amplitude Meter is equipped with a meter calibrated directly in three ranges of 0.1, 1.0 and 10.0 mills full scale

reading. Applications for the new IRD Model 305 include three major categories: inspection, production and preventive maintenance. For example, quality control of electric motors, fan assemblies, blowers, compressors and any rotating equipment where a balance or vibration specification is prescribed. Receiving Inspection may utilize the instrument for inspection of incoming assemblies and rotating components. Another application of the new model is for machine tool maintenance. For example, acceptable vibration tolerances may be established for machine tools to assure production within specified tolerances of finish and dimension. Routine inspection is then made of the machine tools, vibration level recorded, and when excessive vibration is present, other vibration analyzing equipment may be used for further analysis and correction of the vibration.

★ ★ ★



It is now possible to select a completely standard Indicator Depth Gage for practically any part condition by utilizing a standard series of interchangeable gage components being marketed by the **A. G. Davis Gage & Engineering Co.**, 21435 Dequindre Road, Hazel Park, Mich. By selective variation of components over 3500 standard depth gages may be specified to gage special dimensions. No alteration of standard components is required. Complete depth gages may be ordered by combining the selected component model numbers, eliminating the necessity of design drawings in most cases. Where permanent record drawings are desirable or required, full scale tracing templates are available on request. Standard models may be easily set to either gage blocks or a master set gage. Any of the popular makes of indicators may be furnished with the gage.

★ ★ ★

Allegany Instrument Co., 1091 Wills Mountain, Cumberland, Md., has introduced a high rate tensile and compressive tester, Model 625. New materials as well as new design

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and manufacturing techniques now demand comprehensive testing at deformation rates comparable to those the product actually encounters in use. This need has led to the development of the ALINCO Model 625 High Rate Tension and Compression Tester, which provides a completely calibrated stress-strain record of the deformation of a specimen, at rates as high as 6000 inches per minute. Thorough investigation of ultimate yields, elastic moduli, temperature effects, etc., can be obtained at reasonable cost by non-skilled personnel. To test a material, the operator clamps a specimen in the tension or compression jaws of the machine. He then depresses the CALIBRATE button, and a series of dots are placed on a photographic record by the electronic section of the High Rate Tester in a fraction of a second. These dots represent increments of stress in the vertical direction, and strain in the horizontal direction. The operator then depresses the OPERATE button and the specimen is distorted at a constant preselected rate. Both the distortion (strain) and the load (stress) is photographically recorded as a stress-strain curve. In addition, timing dots are put on the record while the specimen is being stressed. Further information is available from the manufacturer.

★ ★ ★

NEW LITERATURE

A new four-page catalog sheet, detailing its Strain Gage Apparatus, Model BL-1516, has just been released by the Brush Electronics Co., 3405 Perkins Avenue, Cleveland 14, Ohio. The instrument is a versatile unit for measuring both static and dynamic strain when used with the appropriate strain gage or resistive transducer. The frequency range of strain measurements covered by the instrument is from static, utilizing the built-in large scale meter, up to

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A S Q C Members. . . . .

We need your help in checking our records

The 1957-58 issue of the ASQC Membership Roster is now being prepared for publication this Fall.

If you have had any changes in your home address, company name or address, job title, or any other corrections that should be made, please fill out the blank at the left and return to National Headquarters at once.

Deadline for returning this form is **June 28, 1957.**

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50,000 cps with the appropriate readout device and accessories.

Visi-Trol Engineering Co., 9345 Hubbell, Detroit 28, Mich., has published a 4-page illustrated bulletin covering their line of free-standing portable inspection cabinet assemblies; eye-level quality control chart stands and chart holders; self-stacking steel storage racks and portable rotating storage drums for line storage, conveyor carrier or in-process operations.

A 19-page illustrated catalog of Electrolimit Comparators and auxiliary equipment has been published by Pratt & Whitney Co., Inc., Charter Oak Blvd., W. Hartford 1, Conn.

A new 6-page folder describing the Webber Micro-Accurate Optical Height Gage is announced by Webber Gage Co., 12912 Triskett Road, Cleveland 11, Ohio. The bulletin describes the various features of the Webber Optical Height Gage which measures heights up to 61 inches with accuracies of plus or minus 0.000005 per inch of height. The gage combines Webber Gage Blocks and the Leitz Measuring Microscope to create an entirely new principle of height measurement.

A new six-page folder, illustrating and describing its direct writing recording systems, has been released by the Brush Electronics Co., 3405 Perkins Avenue, Cleveland 14, Ohio. The folder covers the company's line of oscillographs, amplifiers, its penmotor, plus accessories and supplies used with the basic instrumentation. The folder also lists application information, plus application and design features of many of the instruments covered.

A 4-page illustrated bulletin on the Proficorder is available from Micrometrical Mfg. Co., 345 South Main St., Ann Arbor, Mich. The Proficorder is an instrument for research, experiment and production, designed to afford a flexible, accurate means for showing the true profile of practically any machined or finished surface.

Ways to use low-cost optical instruments to simplify and speed manufacturing and inspection operations are outlined in a new booklet published by the Bausch & Lomb Optical Co., 625 St. Paul St., Rochester, N. Y. The booklet, "Industrial Optical Aids," contains up-to-date information on a wide assortment of inexpensive precision optical instruments and suggests ways to use them to gain faster, easier, lower-cost production. Items discussed include magnifiers, microscopes, wide field tubes, microscopes and comparators.

A Reference Table for Engineers and Quality Control people in wall chart form has been published by Precision Equipment Co. Included are common conversions such as inches to centimeters or watts to horsepower, as well as many conversions that are difficult to locate in reference manuals. For a free copy of the wall chart, write to Precision Equipment Co., 3716 North Milwaukee Ave., Chicago 41, Ill.

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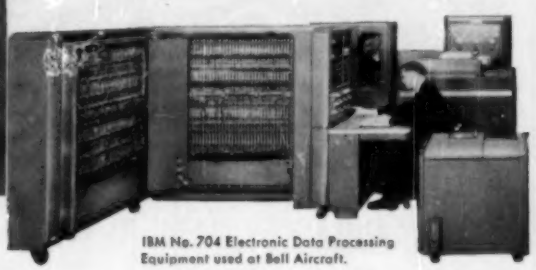

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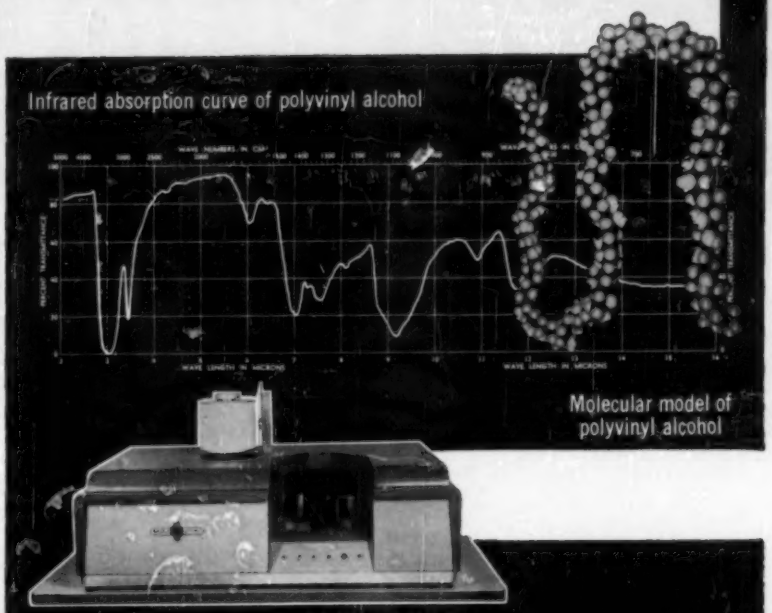

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